BHARATIYA JYOTISH SASTRA

BY

SANKAR BALAKRISHNA DIKSHIT

PART II

History of Astronomy during the Siddhantic and Modern Periods

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of
BHARATIYA JYOTISH SASTRA

(History of Indian Astronomy)

by

Sankar Balakrishna Dikshit

[Translated by Prof. R. V. Vaidya, M. A. B. T.]

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PREFACE

A treatise in Marathi "Bharatiya Jyotish Sastracha Prachin Ani Aryachin Itihas" by Sankar Balakrishna Dikshit, first published in the year 1896, is perhaps the only book on the history of the Indian Astronomy from ancient to modern times. Publication of an English translation of this monumental work was undertaken by the Meteorological Department of India in accordance with a recommendation by the late Professor M. N. Saha, D.Sc., F.R.S., Chairman of the Calendar Reform Committee. The first part of the English translation of this treatise, namely, "Bharatiya Jyotish Sastra, Part I" containing a history of Indian Astronomy in the Vedic and Vedanga period from ancient times upto 1000 B.C. was published by this department in 1968. The present volume contains an English translation of the remaining parts of the original treatise on the Siddhantic and the Modern periods.

The translation of this treatise from Marathi to English was made by the late Professor R. V. Vaidya, a Marathi scholar and former Superintendent of Shree Jiwaji Observatory of Ujjain. He was also a member of the Calendar Reform Committee. This translation was also touched up by the late Professor P. C. Sen Gupta, a renowned Professor of Hindu Astronomy of the Calcutta University. The final editing of this volume has been made under the supervision of Shri A. Bandyopadhyay, Director, Positional Astronomy Centre of the Department at Calcutta. We expect this English translation of Dikshit's excellent treatise will help scholars, both in India and abroad, to appreciate the remarkable achievement of Indian Astronomy during the ancient and medieval periods.

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New Delhi-110003.
16 September, 1981
(25 Bhadra, 1903 S.E.)

P. K. DAS,
Director General of Meteorology.

BHARATIYA JYOTISH SASTRA

PART II

History of Astronomy during the Siddhantic and Modern Periods

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(2) : *ADHIKĀRA ON TRUE PLACES*

Chapter I—True Places and Motions of Planets

TRANSLITERATION

The scheme of transliteration of Sanskrit alphabets into Roman script adopted in this publication is the same as generally followed. The corresponding scripts are given below :

अ	आ	इ	ई	उ	ऊ
a	ā	i	ī	ū	ū
ऋ	लृ	ए	ऐ	ओ	औ
ṛ	ḷ	e	ai	o	ou
क्	ख्	ग्	घ्	ङ	
k	kh	g	gh	ṅ	
च्	छ्	ज्	झ्	ञ	
c	ch	j	jh	ñ	
ट्	ठ	ड्	ढ्	ण्	
ṭ	ṭh	ḍ	ḍh	ṇ	
त्	थ्	द्	ध्	न	
t	th	d	dh	n	
प्	फ्	ब्	भ्	म्	
p	ph	b	bh	m	
य्	र	ल्	व्	श्	
y	r	l	v	ś	
ष्	स्	ह	ं	ः	
ṣ	s	h	ṃ	ḥ	

PART TWO

HISTORY OF ASTRONOMY
IN
JYOTIṢA SIDDHĀNTA PERIOD

1 GAṆITA SKANDHA (MATHEMATICAL BRANCH)

A : Madhyamādhikāra (Adhikāra on Mean Places)

CHAPTER I

History of astronomical Works and Computation of mean places of Planets etc.

FOREWARD

As mentioned in the INTRODUCTION,* the author proposes to discuss the History of the science of Astronomy from about 500 years before Śaka era to this day ; and in the beginning, this first chapter of the *Madhyamādhikāra* (i.e. a section on mean places) under the GAṆITA SKANDHA (i.e. a Branch of Mathematics) will deal with the history of astronomical works and the question of computing the mean motions and places of planets.

The knowledge of astronomy as developed during the Vedic and Vedāṅga Jyotiṣa periods and described in Part I, was considerable as compared with the pace of general progress during the period ; but it would appear very meagre, when compared with the ability (developed in a later period) to predict the true positions of planets. It appears that some works might have been compiled during the interval between these periods. There may be some Saṃhitā works of that type ; but they are either not available now or have not been seen by him. The period of Siddhāntic astronomy can somehow be linked with the ancient period. This point will be discussed later on ; but we have no information as to how the knowledge of astronomy reached the highest stage of calculating the true motions and places of planets, how observations used to be taken and how the motions of planets were finally fixed after comparing the different observations. The oldest of astronomical (Siddhānta) works reveal a sudden rise in the standard of astronomical knowledge. Those who raised the standard of such knowledge through their works were naturally regarded as superhuman, and thus arose the popular belief that the available ancient works on mathematical astronomy are regarded as 'apauruṣeya' (i.e. not compiled by any mortal man), and it is clear that this belief has been formed later.

Because these works were regarded as superhuman, they naturally did not include the description of subjects like observations. There seems to be another very strong reason for this omission. Looking to the conditions of those days when as a rule 'shorter the works, the easier they were to commit to memory', such works dealt with only the rules of calculating the motions and places of planets, and they appear to have avoided length by omitting the underlying theory.

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*Pulished in part I of the book

The author proposes to deal with all works on astronomy in chronological order in this chapter on mean places. Their points of differences, if any, with matters pertaining to other Adhikāras from different works, as also some special points worth mentioning, have been treated in subsequent chapters ; otherwise, all information about the works has been given in this very chapter on mean places. Some works are considered divine while some authors have more than one book to their credit ; hence, the following account is arranged under the names of authors, and at places, under the titles of their works.

The oldest known works on astronomy are the five Siddhāntas—the Sūrya Siddhānta and others. These are regarded as divine. They are again of two kinds. The Pañcasiddhāntikā of Varāhamihira mentions the Saura and other four Siddhāntas ; but at present they are not available. The Pañcasiddhāntikā simply provides clues to their elements. The author calls them the 'ancient Siddhānta Pañcaka' or 'group of five ancient Siddhāntas'. There are five other Siddhāntas likewise entitled the Saura, which are at present available. He calls them 'the modern group of five Siddhāntas'. These will presently be dealt with. First he takes up for consideration the group of five ancient Siddhāntas. These belong to the 5th century before Śaka era. Some of them may belong to an even earlier period.

The group of five ancient Siddhāntas

The following are the Siddhāntas mentioned by Varāhamihira :—

पौलिशरोमकवसिष्ठसौरपैतामहास्तु पंचसिद्धांता: ।।

Pauliśa, Romaka, Vasiṣṭha, Saura and Paitāmaha are the five Siddhāntas.

The elements described by the Pañcasiddhāntikā show that the Siddhāntas were different from the five modern Siddhāntas. Not only are these not available at present, but even the original work, entitled Pañcasiddhāntikā is not available and so, not much is known to any one on this side. Two copies of the work brought from Kashmir by Dr. Buhler are preserved in the Government collection of Manuscripts in the Deccan College (*See* Reg. No. 37 of 1874-75 and No. 338 of 1879-80) ; but these are very incorrect and incomplete and one is unable to find, at places, where one āryā (couplet) ends and the next one begins. The author has written out for himself a copy from the two versions, and calculations made therefrom have shown that the Sūrya and other Siddhāntas described in it, are different from the modern ones, in that they differ in the length of the year and the motions of planets. The astronomical works compiled during the last 800 years do not show that any one knew that there existed before a Sūrya-Siddhānta different from the modern one. He came to know of their existence in 1887 and no doubt need be entertained about it, since this can be proved by calculations and by other evidence. The booklet of the Pañcasiddhāntikā is very incorrect and the major portion of it is unintelligible for want of a commentary ; however many important points have been understood.. *The author would, therefore, describe briefly the five Siddhāntas in the order of the dates of their compilation as found by him.

*Dr. Thibaut published in 1889 A.D. the Pañcasiddhāntikā based on the Deccan College versions. It also gives a new commentary by Sudhākara Dvivedī. The author could not find time to read the whole of it uptil now. However all the important information which he could glean from the Pañcasiddhāntikā has already been given above.

Varāhamihira, in the very first chapter of Pañcasiddhāntikā, observes as follows :—

पौलिशाति* विस्फुटोसौ तस्यासन्नस्तु रोमकः प्रोक्तः ।।
स्पष्टतरः सावित्रः परिशेषौ दूरविभ्रष्टौ ।। ४ ।।

"The Siddhānta made by Pauliśa is accurate ; near to it stands the Siddhānta by Romaka ; more accurate still is the Sāvitra (Saura). The two remaining ones are far from truth."

This shows that the Pauliśa Siddhānta was very clear at the time of the compilation of Pañcasiddhāntikā, which means that its calculations very much agreed with the actual observed positions. The Romaka was nearer to it in correctness. The Sūrya-Siddhānta was better than both and the remaining two (Vasiṣṭha and Pitāmaha) were far removed from correctness meaning that their calculations did not agree with the observed results. The Pitāmaha Siddhānta and Vasiṣṭha Siddhānta must have been the oldest of the five, and of the these two, in the author's opinion, Pitāmaha Siddhānta must have been the more ancient. The reasons for this will be given later on. Let us now consider the Pitāmaha Siddhānta.

PITĀMAHA SIDDHĀNTA

The Subject matter

The basic principles underlying the Pitāmaha Siddhānta have been given in the 12th chapter of the Pañcasiddhāntikā. That chapter contains only five *ārysā* (couplets). Nowhere else in the Pañcasiddhāntikā is found anything about this Siddhānta. The first two of the five couplets run thus :—

रविशशिनोः पंच युगं वर्षाणि पितामहोपदिस्टानि ।। अधिमासस्त्रिंशद्भिर्मासैरवमस्त्रिषष्टयान्हां ।।
द्व्यूनं शकेंद्रकालं पंचभिरुद्धृत्य शेषवर्षाणां ।। द्युगणं माघसिताद्यं कुर्यादिद्युगणस्तदन्युदयात् २ ।

"According to the teaching of Pitāmaha, five years constitute a yuga of the sun and the moon. The adhimāsas occur after thirty months and an omitted lunar day (avam) once in sixty three days. Lessen the time of the Śaka King by two and divide the remainder by five ; with the remaining years find the ahargaṇa, counting from the first day of the light half of Māgha. The Ahargaṇa thus found begins with sunrise".

The fifth couplet describes the method of calculating the length of the day :—

द्विघ्नं शशिरस (६१) भक्तं † द्वादशहीनं दिवसमानं ।।

"Multiplying (the number of days elapsed after winter solstice or the number of days to go before the end of the ayana beginning with summer-solstice) by 2 divide by 61. Add 12 (muhūrtas) to the quotient, and the result will be the length of the day".

*The author copied out the couplets from the Pañcasiddhāntikā, exactly as they are written in his book. Dr. Thibaut has introduced new readings in the next and he has accepted at places only such of them which were considered suitable.

†The word 'hinam' in this couplet is incorrect ; the proper word must be 'yukta m'. The first half of the couplet is incorrect and has not, therefore, been given here, but it means nothing more than that has been given above within brackets.

This verse and the following, describing the method of calculating the nakṣatra, and stating that the nakṣatra should be counted from the Ḍhaniṣṭhā onward, show that the Pitāmaha Siddhānta has some similarity with the Vedāṅga Jyotiṣa system.

Date of Compilation

The method followed by Varāhamihira in explaining the Pitāmaha Siddhānta involves Śaka era but it has been used simply to calculate the 'ahargaṇa'. The methods attributed to other Siddhāntas also direct one to calculate the 'ahargaṇa' from Śaka 427. Just as this does not imply that the Siddhāntas were compiled (by Varāhamihira himself), in Śaka 427, it cannot be taken to imply that the Pitāmaha Siddhānta was compiled after the beginning of Śaka era. It is evident from its similarity with the Vedāṅga Jyotiṣa system that it must have been more ancient than the beginning of Śaka era. There are, however, no means to fix up the date of its compilation.

Āryabhaṭa I has, in the beginning of *Daśagītika* written the following benedictory verse :—

प्रणिपत्यैकमनेकं कं सत्यां देवतां परं ब्रह्म ।। आर्यभटस्त्रीणि गदति गणितं कालक्रियां गोलं ।।१।।

"After saluting the Pitāmaha (kaṃ) who is manifold and one at the same time, the god of truth and the Parabrahma, Āryabhaṭa describes the three subjects *viz.* mathematics, method of calculating time and the celestial spheree and in his last couplet he observes,

आर्यभटीयं नाम्ना पूर्वं स्वायंभुवं सदा सद्यत् ।।

"The science known as the Āryabhaṭīya is the same as the science originaly expounded by Brahmā himself".

This shows that the Pitāmaha Siddhānta must have been compiled long before Āryabhaṭa lived (*i.e.* Śaka 421)

Brahmagupta (Śaka 550) , in his Siddhānta, observes,

ब्रह्मोक्तं ग्रहगणितं महता कालेन यत्खिलीभूतं ।। अभिधीयते स्फुटं तत् जिष्णुसुतब्रह्मगुप्तेन ।।२।
अध्याय १

"The calculation of planets' places as propounded by Brahmā has, become disjointed on account of (lapse of) long time ; Brahmagupta, the son of Jiṣṇu, is describing the same in clearer terms".

There are three Brahma Siddhāntas available at present. One is the Brahma Siddhānta by Brahmagupta, the second, the Brahma Siddhānta mentioned in Śākalya Saṃhitā and the third that included in Viṣṇudharmottarapurāṇa. In the Author's view, to be explained later, the Viṣṇudharmottara and the Śākalyokta Brahma Siddhāntas are not older than the Brahmagupta's time, but compiled much later. The basic principles, propounded by the Śākalya Brahma Siddhānta, even it be more ancient than Brahmagupta, are exactly the same as those propounded by the modern Sūrya-Siddhānta. It may as well be said to be in current use and not antiquated or disjointed ; and it will be shown further that the Viṣṇudharmottara Brahma Siddhānta is

not similar to the Brahmagupta Siddhānta. This shows that the Brahma Siddhānta to which Brahmagupta has referred as containing mathematics explained by Brahmā, must have been different from the Brahma Siddhāntas of Śākalya Saṃhitā and Viṣṇudharmottarapurāṇa and it must be the same as the Pitāmaha Siddhānta of the Pañcasiddhāntikā. The Vedāṅga Jyotiṣa does not deal with the calculation of planets other than the sun and the moon; and the Pitāmaha Siddhānta of the Pañcasiddhāntikā also describes the calculations of the sun and the moon only. Varāhamihira has given the calculations of all planets in the case of only the Sūrya-Siddhānta out of the five Siddhāntas and mentions nothing about the planetary calculations contained in the Pitāmaha Siddhānta. It must have, however, contained the calculations of planets as remarked by Brahmagupta, and Varāhamihira appears to have omitted it, on finding that it did not agree with the actual observed places on account of lapse of time. A Pitāmaha Siddhānta, different from the one described in the Pañcasiddhāntikā, does not appear to have ever existed before Brahmagupta. The words "planetary calculations given by Brahmā" occurring in Brahmagupta's work must certainly be referring to the Pitāmaha Siddhānta of the Pañcasiddhāntikā, and the remark, "a long time has elapsed" also refers to the same Pitāmaha Siddhānta. It follows, therefore, that it must have been compiled long before the Śaka era.

Āryabhaṭa and Brahmagupta appear to have expressed veneration for the Pitāmaha Siddhānta only as a formality, because their siddhāntas and the Pitāmaha Siddhānta of the Pañcasiddhāntikā have nothing in common. It has already been pointed out in the course of the study of the Vedāṅga Jyotiṣa that Brahmagupta has openly found fault with the five-year Yuga system. Still, these arguments in no way affect the inference that there existed a Siddhānta knowr as the Pitāmaha Siddhānta before these two astronomers lived.

The System

The Pañcasiddhāntikā gives in the beginning two couplets relating to the Pitāmaha Siddhānta, the first of which contains the expression,

अधिमासस्त्रिंशद्भिर्मासैः

meaning, "an intercalary month to be reckoned after 30 months". It has been shown in the study of Vedāṅga Jyotiṣa that the adoption of an intercalary month after 30 months causes a grave error; but this very couplet has been cited by Bhaṭotpala in his commentary on Vṛhatsaṃhitā in connection with the verse "*ekaikamabdeṣu*" in Chapter 8. The reading there is "*adhimāso dwyagnisamairmāsaiḥ*" which means that an intercalary month is to be reckoned after 32 months. Again the same couplet is found in the commentary (Chapter I) by Mahādeo on Śrīpati's Ratnamālā and it also gives "adhimāso dwyagnisamaiḥ" as the reading. It is strange that there is room for confusion due to doubtful readings at such an important place.

If it be assumed that Utpala and Mahādeo changed the original reading *viz.* "triṃśatbhirmāsaiḥ", why should they have substituted "dwyagnisamaiḥ" as the reading? The intercalary month occurs after more than 32½ months, and hence, they could have as well substituted some words meaning 32½ or 33. It appears, therefore, that "dwyagnisamaiḥ" must have been the original reading. According to the Vedāṅga Jyotiṣa one day (tithi) is suppressed after 62 days, while the above couplet mentions the suppression of one day

as occuring after 63 days (tithis). This shows that the Vedāṅga Jyotiṣa and the Pitāmaha Siddhānta are not similar to each other completely, and this also lends an additional support to the view that "dwyagnisamaiḥ" must have been the original reading.

The number of intercalary months in 8 years comes to be 3 at the rate of one intercalary month in 32 months. This gives 99 as the number of lunar months in 8 years and 2970 as the number of tithis (lunar days) ; and $47\frac{1}{7}$ lunar days will be suppressed during this number of tithis at the rate of one suppressed tithi per 63 lunar days. Hence, 8 years will be equal to $2922\frac{6}{7}$ sāvana days or one year will be equivalent to 365 days and $21\frac{3}{7}$ ghaṭis. This measure of a year is more accurate than that found in the Vedāṅga Jyotiṣa.

The Pitāmaha Siddhānta existed before Āryabhaṭa, Varāhamihira, and Brahmagupta. As it had fallen into disuse in their times it is evident that it must have been compiled long before them. It is similar to the Vedāṅga Jyotiṣa but differs from it much. Brahmagupta's statement shows that it (the Pitāmaha Siddhānta) contained the calculations of Mars and other planets, which is not given in the Vedāṅga Jyotiṣa. It proves that a more accurate work known as the Pitāmaha Siddhānta was compiled sometime after the Vedāṅga Jyotiṣa and this is an important fact. If it were known how the places of Mars and other planets used to be calculated according to the Pitāmaha Siddhānta, it would have been found very useful in tracing the growth of Indian astornomy ; but we have almost no hopes of obtaining the Pitāmaha Siddhānta now in its original form.

VASIṢṬHA SIDDHĀNTA

The Date

The Pañcasiddhāntikā contains 13 āryās (couplets) relating to Vasiṣṭha Siddhānta. The system described by it is somewhat different from that met with in other siddhāntic works. This fact and also the statement of Varāhamihira that "Vasiṣṭha is very inaccurate" leads one to infer that it must have been more ancient than the remaining three siddhāntas excepting the Pitāmaha Siddhānta.

The System

The thirteen couplets show that they mention nothing about planets other than the sun and the moon. The method of calculating tithis and nakṣatras is not similar to that of the present day. It mentions the rāśi (sign), aṃśa (degree) and Kalā (minutes) as the units and the subject of 'shadow' has been considered at length. Something has been told about the length of the day and the word 'lagna' (ascendant) has been used in a somewhat present day sense. The Vasiṣṭha Siddhānta, available at present, is in no way similar to the one existing before Varāhamihira's time and did not exist in his time. This question will be discussed again later on.

Different versions of Vasiṣṭha and Romaka Siddhāntas

Two versions of the Vasiṣṭha and Romaka Siddhāntas were known at the time of Brahmagupta (Śaka 550). The case of Romaka Siddhānta will automatically be considered along with the evidence on the basis of which it is to be proved that there were two kinds of Vasiṣṭha Siddhānta. Let both of them, therefore, be considered here together.

Brahmagupta says at one place in his Siddhānta,

पौलिशरोमकवासिष्ठसौरपैतामहेषु यत्प्रोक्तं ।। तन्नक्षत्रानयनं नार्यभटोक्तं तदुक्तिरतः ।। ४१ ।
अध्याय १४

"I describe the 'nakṣatrānayana' i.e. the method of calculating nakṣatras, which has been given by other Siddhāntas *viz.* Pauliśa, Romaka, Vāsiṣṭha, Saura and Paitāmaha but not given by Āryabhaṭa".

He observes at another place,

अयमेव कृतः सूर्येंदुपुलिशरोमकवसिष्ठयवनाद्यैः ।।
अध्या. २४ आर्या ३.

"This very (beginning of a yuga) has been adopted by Sūrya, Indu, Puliśa Romaka, Vasiṣṭha and Yavana".

Brahmagupta has cited as authority of the Sūrya and other Siddhāntas because these were in his favour. The Brahmagupta Siddhānta as a whole, appears to have launched a vigorous attack against Āryabhaṭa and others. He is, as it were, showering volleys of vituperation. Even then he has not made any direct attack against the group of first (Sūryādi) five Siddhāntal except the Romaka, and he has explicitly found fault with the Pattern, ony once, as may be seen from the following couplet :—

युगमन्वंतरकल्पाः कालपरिच्छेदकाः स्मृतावुक्ताः ।।
यस्मान्न रोमके ते स्मृतिबाह्यो रोमकस्तस्मात् ।। १३ ।।
अध्याय १.

"The smṛti works mention yuga, manvantara and kalpa as the broad units of time. The Romaka has violated the Smṛtis since it does not mention them".

Brahmagupta, at another place, observes,

लाटात्सूर्यशशांकौ मध्याविंद्वच्चचंद्रपातौ च ।।
कुजबुधशीघ्रबृहस्पतिसितशीघ्रशनैश्चरान् मध्मान् ।। ४८ ।।
युगयातवर्षभगणान् वासिष्टान् विजयनंदिकृतपादान् ।।
मंदोच्चपरिधिपातस्पष्टीकरणाद्यमार्यभटात् ।। ४९ ।।
श्रीषेणेन गृहीत्वा रत्नोच्चयरोमकः कृतः कंथा ।।
एतान्येव गृहीत्वा वासिष्टो विष्णुचंद्रेण ।। ५० ।।
अध्याय ११.

The gist

"Śrīṣeṇa has compiled a 'kanthā' (i.e. a patch work) entitled as Romaka, by borrowing elements from different Siddhāntas, e.g. (i) mean sun and moon,

moon's apogee, moon's node, Mars, Mercury, Jupiter, Venus, and Saturn from Lāṭa's work (ii) elapsed years of yugas and bhagaṇa (sidereal revolutions) from Vasiṣṭha (iii) the pāda (quadrants) from Vijayanandi's works and (iv) mandocca, aphelia, paridhi (epicycle), nodes of planetary orbits and calculations of true places from Āryabhaṭīya. Viṣṇucandra has similarly, compiled the Vasiṣṭha Siddhānta by borrowing the same elements".

It has been said above that Viṣṇucandra has borrowed the same elements from other works in compiling the Vasiṣṭha Siddhānta as Śrīṣeṇa had borrowed in compiling the Romaka Siddhānta, and it has also been observed that Śrīṣeṇa took the bhagaṇas and the elapsed years of yugas from the Vasiṣṭha This shows that Viṣṇucandra also adopted the same elements from the Vasiṣṭha Siddhānta and other information from other Siddhāntas and compiled another Vasiṣṭha Siddhānta. It, therefore, shows that there existed two kinds of Vasiṣṭha Siddhāntas and that this was known to Brahmagupta. One of them was the original Vasiṣṭha Siddhānta and the other was Viṣṇucandra's Vasiṣṭha Siddhānta, compiled by borrowing some elements from the first.

It has already been remarked before that Brahmagupta has abused Romaka Siddhānta as 'a violator of Smṛti', because it does not give the time units of yuga, manvantara and kalpa ; but it has also been shown above that Brahmagupta himself says that Śrīṣeṇa picked up the figures for 'elapsed years of yuga', from the Vasiṣṭha Siddhānta while compiling the Romoka Siddhānta. Similarly, he again observes,

तद्युगवर्षो महायुगमुक्तं श्रीषेणविष्णुचंद्राद्यैः ।।

अ० ११ आर्या ५५.

मेषादितः प्रवृत्ता नार्यभटस्य स्फुटा युगस्यादौ ।। श्रीषेणस्य कुजाद्याः

अ० २ आ० ४६.

"That Śrīṣeṇa, Viṣṇucandra and other authors have mentioned 'Mahāyugas as a multiplicity of yugas"...

"Śrīṣeṇa has not given true positions of Mars and others from the commencement of a yuga, as is done by Āryabhaṭa, but from the beginning of Meṣa".

Thus, according to the statement of Brahmagupta himself, the Romaka Siddhānta by Śrīṣeṇa did contain the yuga system and from this (it can be inferred that) there were two siddhāntas named Romaka, at the time of Brahmagupta— the one known as the original Romaka Siddhānta and the other, that 'compiled by Śrīṣeṇa'.

Most of the names of astronomers who lived before Brahmagupta and who have been mentioned in his Siddhānta, are found in the Pañcasiddhāntikā. However, the names of Śrīṣeṇa and Viṣṇucandra are not found in the Pañcasiddhāntikā which mentions only one Siddhānta each, named as Vaśiṣṭha and Romaka. This goes to show that Śrīṣeṇa's Romaka Siddhānta and Viśṇucandra's Vasiṣṭha did not exist before Śaka 427, and that only the original Romaka Siddhānta and the original Vasiṣṭha Siddhānta existed then and these are given in the Pañcasiddhāntikā only in summary form. According to Brahmagupta, Śrīṣeṇa and Viṣṇucandra borrowed the method of finding true places from Āryabhaṭa. This also shows that they compiled their res-

pective Siddhāntas after Śaka 421 while the Pañcasiddhāntikā leads to the conclusion that they were compiled after the Śaka 427.

ROMAKA SIDDHĀNTA

It has been pointed out above that out of the two Romaka Siddhāntas described, only the original Romaka Siddhānta existed at the time of the Pañcasiddhāntikā. Let us now consider this Romaka Siddhānta.

A large portion of the Pañcasiddhāntikā has been devoted to Romaka Siddhānta. Three couplets of the first chapter beginning from the 8th describe the method of finding the 'ahargaṇa'. The fifteenth couplet mentions the intercalary months and the suppressed tithi. All the 18 'āryās' of the 8th chapter are devoted to Romaka Siddhānta. They describe the calculations of the sun and moon, their true places and the method of calculating solar and lunar eclipses.

The very first couplet giving the method of calculating the 'ahargaṇa' according to the Romaka Siddhānta runs thus :—

सप्ताश्विवेद (४२७) संख्यं शककालमपास्य चैत्रशुक्लादौ ।।
अर्धास्तमिते भानौ यवनपुरे भौमदिवसाद्यः ।। ८ ।।
अध्याय १.

"Deduct the Śaka year 427 from the number of that year for which the ahargaṇa is wanted at the beginning of the light half of Caitra, when the sun was halfset in Yavanapura, at the beginning of Tuesday".

This shows that the first lunar day of Caitra was a Tuesday.

A Karaṇa work is required to give the positions of planets as at the beginning or epoch of that work, for finding the planetary positions. These positions are termed 'kṣepaka'. The 'kṣepakas' as mentioned by the Pañcasiddhāntikā prove to be true for the mean Meṣādi (Sun's entry into Aries), falling on the 14th Lunar day of the dark half of 'amānta' Caitra of Śaka 427 ; i.e. on Sunday, the 20th of March, 505 A.D. There is no doubt that some of them are true for the moon and others for the midnight of that date. This point will be more clearly explained in the study of the Sūrya-Siddhānta later on. The next Śukla 'pratipadā' (i.e. the first lunar day) after the 14th day of the dark half of Caitra, i.e. the first day of the light half of Vaiśākha, is seen to fall on Tuesday. Evidently this very 'pratipadā' was called the 'Caitra-śukla-pratipadā', by Varāhamihira (otherwise, by no other method the Caitra-śukla-pratipadā of Śaka 427, can be shown to fall on Tuesday), and it was no doubt correct that the 'ahargaṇa' is required to be calculated from that day. Varāhamihira appears to have adopted this epoch, because it is convenient to calculate positions from those on the 1st day of the light half. It is a well known fact of mathematical astronomy that the 'ahargaṇa' calculated with the help of any 'Karaṇa work' proves to be correct within a day, and it has to be verified with the help of the day of the week. It may now be questioned as to why the Vaiśākha śukla-pratipadā could have been called the Caitra-śukla-pratipadā by Varāha. I have absolutely no doubt that the śukla-pratipadā following the day for which the Kṣepakas are given is the first day of the Vaiśākha-śukla-halfmonth of Śaka 427 according to the 'amānta' system. The Caitra is

defined as that ending lunar month which ends while the sun is in Meṣa (Aries). As the sun is found to be in Meṣa at the end of that amāvāsyā which fell on the day, next to the day for which the elements have been given irrespective of whether a mean or a true Meṣa was reckoned; and hence, according to the above definition the amānta lunar month which ended with the amāvāsyā must be termed as Caitra, and Vaiśākha commenced on Tuesday i.e. the next day. But a lunar month belonging to the pūrṇimānta system ends on the full moon day, and hence, the full moon day belonging to that light half which commenced just after the 'kṣepaka' day will coincide with the end of the lunar month. The calculations made on the basis of 'kṣepakas' given by Pañcasiddhāntikā show that the sun still occupied the Meṣa sign, and, hence that lunar month naturally received Caitra as its name. The author does not find any other convincing theory to explain how that month could be termed Caitra. The pūrṇimānta system has remained in vogue in Northern India from a very ancient time. Even though the 'pūrṇimānta' system is still in vogue there, the lunar months are not named according to the system described above; but it appears that the system must have been in use in its pure form at the time of Varāhamihira.

The first couplet of the 8th Chapter gives tne method of finding the sun's place according to the Romaka Siddhānta :—

सेमकसूर्यो द्युगणात् खतिथि(१५०) घ्नात् पंचकर्तु (६५) परिहीनात् ॥
सप्ताष्टकसप्तकुतेंद्रियो ५४७८७ द्गतान्मध्यमार्कः सः ॥

"Multiply the ahargaṇa by 150, deduct 65, and divide the remainder by 54787 ; the result is the mean longitude of the sun".

The sun's position is obtained by multiplying the ahargaṇa by 150, subtracting 65 from the product and by dividing the remainder by 54787. The number 65 is to be subtracted from this because of the Kṣepaka. The figure denoting the sun's longitude is obtained in terms of bhagaṇas etc. (the bhagaṇa means a complete sidereal revolution of a planet through the Zodiac.) There is no doubt about this, although it is not explicit in the couplet. The sun makes 150 complete revolutions in 54787 days and hence, one revolution requires exactly 365 days 14 ghaṭis 48 palas. This is, therefore, the measure of a year according to Romaka. The modern Sūrya-Siddhānta gives 365d 15g 31p 31·4v. as the measure. Brahmagupta has blamed Romaka for not giving measures of yuga and other units, as is done by other Siddhāntas and the following discussion will show that it is true. In order to facilitate the comparison of Romaka with other Siddhāntas, below the figures are given indicating the number of revolutions and other measures relating to the moon in one Mahāyuga i.e., in 4320000 years, which are derived from the elements given by Romaka. The couplets from the Pañcasiddhāntikā on the basis of which these have been calculated are as follows :—

रोमकयुगकमर्कदोर्वषण्याकाशपंचवसुपक्षः (२८५०)
खेंद्रियदिशो (१०५०) धिमासाः खरकृतविषयाष्टयः (१६५४७) प्रलयाः ॥ १५ ॥

अध्याय १.

"Romaka's yuga consisted of 2850 years. During this period, the number

of intercalary months is 1050 and that of pralaya's or suppressed tithis is 16547".

शून्यैकैका (११०) स्यस्तान्नवशुन्यरसा (६०९) न्विनाह्निनसमूहात् ।।
रूपत्रिखगुण (३०३१) भक्तात्केंद्रं शशिनोस्तगमवंत्याम् ।। ५ ।।
त्र्यष्टक (२४) गुणिते दद्याद्रसर्तुयमषदकपंचकान् (५६२६६) राहोः ।।
भवरूपाग्न्यष्टि (१६३१११) हृते...।। ८ ।।

अध्याय ८.

"(5) Multiply the ahargaṇa by 110, add 609, and divide by 3031 ; the quotient gives the position of the moon's *kendra at Sunset at Avantī.*

(8) Multiply the ahargaṇa by 24, add 56266 and divide by 163111 ; the result is the successive position (in revolutions, signs, etc.) of Rāhu (i.e. the moon's ascending node), reckoning backwards from the end of Pisces (i.e. the first point of Aries). (24 revolutions of Rāhu are supposed to take place in 163111 sāvanadays)".

The following figures denoting several astronomical measures are derived from these couplets and from the above couplet describing the calculation of the sun's position and that describing the calculation of ahargaṇa.

Number giving	*During one Mahāyuga 4320000 years*	*During a yuga of 2850 years*
Revolutions of stars	1582185600	1043803
Revolutions of the Sun	4320000	2850
Sāvana days	1577865600	1040953
Revolutions of the Moon	$57751578\frac{18}{19}$	38100
Revolutions of the Moon's apogee	$488258\frac{13708}{57589}$	$322\frac{228}{3031}$
Revolutions of Moon's ascending node	$232165\frac{109085}{163111}$	$153\frac{26889}{163111}$
Solar Months	51840000	34200
Intercalary Months	$1591578\frac{18}{19}$	1050
Lunar Months	$53431578\frac{18}{19}$	35250
Tithis	$1602947368\frac{8}{19}$	1057500
Suppressed Tithis	$25081768\frac{8}{19}$	16547

The numbers showing the revolutions of the moon etc. in one Mahāyuga are not integral numbers. Hence, the sun and the moon, according to Romaka, will not, like other Siddhāntas, come together in the beginning of the Kaliyuga

or a Mahāyuga. Similarly, the number of lunar months is also not an integral number and the Romaka's yuga has been stated to consist of 2850 years. This shows that the Romaka Siddhānta has not followed the system of adopting 4320000 years as the measure for a Mahāyuga.

The couplet describing the method of calculating the moon's place is very incorrect. The author could not calculate the number of the moon's revolutions from it ; these have been calculated by a different method.

The kṣepakas at the epoch of the Karaṇa work are found to be as follows :—

Sun	11^s	29°	34′	23″	Moon's Kendra .	2^s	12°	19′	57″
Moon	11	29	18	50	Moon's ascending Node . .	7	25	49	3

The Kṣepakas are true for the moment of sunset at Ujjayinī on Sunday the 14th lunar tithi of Caitra Kṛṣṇa, Śaka 427 (i.e. 20th March 505 A.D.).

Hipparchus, the Greek astronomer, lived about 150 B.C. His figure for the length of the year exactly tallies with that of the Romaka (*viz.* 365d—14gh.—48pal.)

The work of Hipparchus is not available at present, but he had compiled tables for calculating the positions of the sun and the moon only and not for calculating the planets. Well known European astronomers say that the latter were compiled by Ptolemy on the basis of the principles of Hipparchus. They also admit* that the principles of Greek astronomy had already reached India long before Ptolemy's time. The Romaka Siddhānta gives the calculations of only the sun and the moon, and its measure of the year is found in no other Siddhānta. It does not describe 'the universally accepted yuga system' and its name. Romaka appears to be western. All these things go to show that the original Romaka Siddhānta was compiled on the lines of the work of Hipparchus, and it must have been compiled after 150 B.C. and before Ptolemy's time i.e. 150 A.D.

It has already been shown above that the Paitāmaha and Vasiṣtha Siddhāntas were older than the Romaka. Similarly, it is thought that even the Sūrya Siddhānta and the Puliśa Siddhānta of the Pañcasiddhāntikā are more ancient than the Romaka ; for, it is obvious from Brahmagupta's work, that the other four Siddhāntas were regarded with more veneration than the Romaka. He has nowhere blamed any of the four works. After the time of Brahmagupta, the Romaka Siddhānta appears to have gone quite out of use, both in its original form and the form in which it was recast by Śriṣeṇa. Utpala has nowhere made references to the Romaka on any occasion in his discussion of planetary calculations in his commentary on the Bṛhatsamhitā, but he has cited the authority of the four Siddhāntas, *viz.*, those by Puliśa, Sūrya, Āryabhaṭai or by Brahmagupta. The original Romaka Siddhānta seems to have disappeared in its original form at the time of Utpala. The Romaka Siddhānta of the present day gives elements according to the modern Sūrya Siddhānta and not according to any other Siddhānta ; and even this Romaka Siddhānta is not much known to any one now-a-days. This shows that the veneration which the other Siddhāntas, out of the group of five, enjoy, is due to their being much more ancient than the Romaka.

*See Grant's History of Physical Astronomy [Introuction page (iii)] and page 439); similarly, see English translation of Sūrya Siddhānta, by Burgess, page 330.

One more important proof about the Romaka being more modern than the five Siddhāntas is given below :

Measures of the year according to different works on astronomy.

	Days	Ghaṭi	Pala	Vipala	Prativipala
Vedāṅga Jyotiṣa	366	..	..	..	..
Pañcasiddhāntikā group :					
1 Pitāmaha Siddhānta	365	21	25	..	..
2 Vasiṣṭha Siddhānta	..	..	..	..	..
3 Puliśa Siddhānta	365	15	30	..	..
4 Sūrya Siddhānta	365	15	31	30	..
5 Romaka Siddhānta	365	14	48	..	..
First Ārya Siddhānta	365	15	31	15	..
Brahmagupta Siddhānta (Modern group)	365	15	30	22	30
Sūrya, Vasiṣṭha, Śākalya, Romaka and Soma Siddhāntas	365	15	31	31	24
Second Ārya Siddhānta	365	15	31	17	6
Rājamṛgāṅka / Karaṇa Kutūhala etc.	365	15	31	17	17½

Out of these figures indicating the measure of the year, none except that of Romaka are found to be smaller than 365d—15gh—30p, and none, excepting that of the Vedāṅga Jyotiṣa and the Pitāmaha Siddhānta, greater than 365d—15gh—32p. In other words, leaving aside the case of Vedāṅga Jyotiṣa and Pitāmaha Siddhānta, none of the rest, except the Romaka, differ from one another by more than 2 palas. Had Romaka been older than the Puliśa Siddhānta and the Saura Siddhānta of the Pañcasiddhāntikā, all of them would have taken the same year measure, as the Romaka or one with a slight variation, and they could not have strayed very far from the Romaka. This proves beyond doubt that the Puliśa and Saura Siddhāntas were older than the Romaka. It seems beyond doubt that all the Siddhāntas of the Pañcasiddhāntikā belonged to a pre Śaka period.

It is Dr. Thibaut's opinion that the Romaka and the Puliśa Siddhāntas of the Pañcasiddhāntikā are "not more modern than 400 A.D." He means* to say that these two were compiled about the year 400 A.D. and the other Siddhāntas of the Pañcasiddhāntikā group were also compiled about the same year. But the above discussion will show that his view is erroneous.

The figures showing the number of revolutions and other elements, as given in the Romaka Siddhānta, which is available at present, are given later on. A comparison of these figures with the foregoing ones will show that there is absolutely no similarity between them. This shows that the modern Romaka Siddhānta did not exist before Śaka 427.

The question whether the modern Romaka Siddhānta is the same as that compiled by Śrīṣeṇa and whether the modern Vasiṣṭha Siddhānta was compiled by Viṣṇucandra, will be discussed later on.

*See Introduction page LX of Pañcasiddhāntikā by Dr. Thibaut

PULIŚA SIDDHĀNTA

A large part of the Pañcasiddhāntikā is devoted to the Puliśa Siddhānta It is stated in the 10th couplet of the first Chapter that Romaka's 'ahargaṇa' is very nearly equal to that of the Puliśa Siddhānta. Then follows the calculation of the place of the luminaries etc. and of the eclipses of the sun and the moon.

It has not at all been stated what the motions and places of Mars and other planets are according to the Puliśa Siddhānta ; but the last couplet states that "the planets have thus been described according to the Puliśa Siddhānta" and which shows that about 16 'āryās' in the end mention something from Puliśa Siddhānta about their direct and retrograde motions, and the rise and set of planets.

The elements pertaining to the Puliśa Siddhānta are found to be as follows :

खार्क (१२०) घ्नेग्निहुताशन (३३) मपास्य रूपाग्निवसुहुताशकृतैः (४३८३१) ॥
हृत्वा क्रमाद्दिनेशो मध्यः... ॥ १४ ॥
अष्टगुणे दिनराशौ रूपेंद्रियशीतरश्मिभि (१५१) र्भक्ते ॥
लब्धा राहोरंशा भगणसमाश्च क्षिपेल्लिप्ताः ॥ ४१ ॥
वृश्चिकभागा राहोः षद्विंशतिरेकलिप्तिकालुप्ताः ॥ ४२ ॥

"(14) Multiply the ahargaṇa by 120, deduct 33, and divide by 43831 the result is the mean longitude of the sun in due order. (41) Multiply the ahargaṇa by 8 and divide the product by 151 ; the quotient indicates the degrees of Rāhu (i.e. the moon's ascending node) to which as many minutes have to be added, as there are complete revolutions. (42) This is a stanzas stating certain correction to be applied to the place of the moon's node as found according to the above rule. Apparently 25 minutes have to be deducted from that place. We do not know what is meant by "Vṛścika-bhāgā Rāhoḥ".

These couplets are found in the chapter following the one consisting of the first 25 āryās, and they form part of the passages attributed to the Puliśa Siddhānta. The elements derived from these āryās are as follows :—

The measure of the year	*365*d *15*gh *30*pal
Number of Sāvana days in one Mahāyuga . .	1577916000
No. of revolutions of Rāhu	$232227\frac{65703915}{67946855}$
Period of Rāhu's one revolution	*6794*d *41*gh *18*pal

This gives for the measure of the year a figure different from that of other Siddhāntas. Similarly, the period of the revolution of Rāhu (the moon's ascending node) is also somewhat different.

The Pañcasiddhāntikā mentions other things from the Puliśa Siddhānta which include the question of true places of the sun and the moon. It describes the method of finding 'carakhaṇḍas' (groups of ascensional differences) from the 'palabhā' (the noon shadow on equinoctial day), and calculating therefrom the length of the day ; terrestrial longitudes too have been considered.

The method of calculating the tithi and nakṣatra is similar to one of the present day. It includes the explanation of the 'karaṇas' and 'Mahāpātas' (or the parallels of the declination of the sun and the moon). The question of eclipses is also considered and the method is almost similar to that of other modern Siddhāntas. The study of the direct and retrograde motions of planets is similar to that described in the work entitled Khaṇḍakhādya. The study 'cara' (ascensional difference) quotes the following couplet.

यवनाच्चरजा नाडय: सप्ता (७) वंत्यास्त्रिभाग (१/३) संयुक्ता: ।।
वाराणस्यां त्रिकृति: (९) साधनमन्यत्र वक्ष्यामि ।।

"The Yavana mentions 7gh 20pal. as the 'cara' for Ujjayinī and 9 ghaṭis for Vārānasī. The method of calculating it, iş described elsewhere".

The word mentions, as in Vedāṅga Jyotiṣa, dinamānavṛddhi, or the increase in the length of a day at the end of Udagayana as compared with that at the end of the Dakṣiṇāyana. According to the sayana almanac, the minimum and the maximum length of the day at Ujjayinī are *26*gh. *26*pal. and *33*gh. *34* pal. respectively; that is, the difference between the two amounts to 7gh. 8p. According to the Grahalāghava these values are 26gh. 21p. and 33gh. 39p respectively and the difference is equal to 7gh. 18p. These have been calculated by assuming 5-8 as the palabhā for Ujjayinī. Pandit Bāpūdeva śāstri gives in his almanac, the maximum length of the day at Vārānasī to be 33gh. 56p. and the minimum length as 26gh. 4HP. The difference between the two comes to be 7gh. 52p. This has been calculated on the basis of 5-40 as the palabhā at Vārānasī. Assuming this very value for Vārānasī, the Grahalāghava calculation shows 8gh. 4pal. as the difference between the two lengths. Assuming 6-15 as the palabhā, one gets a difference of about 9 ghaṭis on the basis of Puliśa's 'Carakhaṇḍa' as given by the Pañcasiddhāntikā.

The third couplet in the Pañcasiddhāntikā shows that Lāṭadeva has written a commentary on the Pauliśa Siddhānta.

The author has neither seen nor heard of any Puliśa Siddhānta of any kind being available at present. Utpala has incidentally quoted about 35 couplets from the Puliśa Siddhānta as authority in his commentary on the Bṛhatsaṃhitā. They contain the number of revolutions and other important elements given by the Puliśa Siddhānta. Those couplets as collected in one place are, therefore, quoted below :—

अष्टाचत्वारिशंत्पादविहीना: क्रमात् कृतादीनां ।। अंशास्ते शतगुणिता ग्रहतुल्ययुगं तद्देकत्वं ।।

(The meaning is not quite clear)

"The number of years* in a Kṛta yuga is obtained by multiplying 48 by 100 and that in the successive Yugas is obtained after multiplying 100 the "number 48 diminished by its quarter (i.e. 12) successively".

This is a unit (ekatvam) to start with in the case of each kind of 'planetery' yugas.

[**Footnote by the translator* :—

Although the text quotes 'aṃśaḥ' as the word, the manuscript, which I could see by the kind permission of the local Scindia Institute, gives the word "abdaḥ", and the explanation therein shows that the Mahāyuga (which was rendered as the 'divine yuga' by the later astronomers) consisted of (4800+3600+2400+1200=12,000 years). According to the prevailing system, the year was of 4 kinds and consisted of 4 kinds of months, each of 30 days of the corresponding denomination].

सावनमकृतं १५५५२०००००० चांद्रं सूर्येंदुसंगमान् दिनीकृत्य (१६०३००००८०) ।।
सौरं भूदिनराशिः १५७७९१७८०० शशिभगणदिनानि १७३२६०००८० नाक्षत्रं ।।

"The natural yuga is termed '*sāvana*' (civil). That which is reckoned after calculating number of days in the joint revolutions of the sun and the moon as *Cāndra* (Lunar); the *Saura* or solar (yuga) is "the heap" of solar days; and the number of days in the revolution of the moon constitutes a *Nakṣatra* (sidereal) yuga".

परिवर्तैरयुतगुणैर्द्वित्रिकृतै (४३२००००) भस्किरो युगं भुंक्ते ।।
रसदहनहुतवहानलशरमुन्यद्रीषवश्चंद्रः (५७७५३३३६) ।।

"The sun completes 4320000 revolutions in one yuga, while the moon makes 57753336 revolutions (in the same period)".

अधिमासकाः षडग्नित्रिकदहनछिद्रशररूपाः (१५९३३३६) ।।
मगणांतरशेषं यत् समागमास्ते द्वयोर्ग्रहयोः ।।
तिथिलोपाः खवसुद्विकदस्राष्टकशून्यशरपक्षाः (२५०८२२८०) ।।

"The intercalary months (adhimāsas) in a yuga amount to 1593336. The number of luni-solar conjunctions is equal to the difference between the bhagaṇas of the sun and the moon. The number of suppressed tithis is 25082280".

दस्रार्थबाणतिथयो लक्षहताः (१५५५२००००००) सावनेन ते दिवसाः ।।
विषया (?) ष्टौ खचतुष्कं विश्व...षोडश चांद्रमानेन ।।
वसुसप्तरूपनवमुनिनगतिथयः शतगुणाश्च (१५७७९१७८००) सौरेण ।।
आर्क्षेण खाष्टखत्रयरसदस्रगुणानिल (?) शशांकाः (१७३२६०००८०) ।।

"The measure of the Sāvana yuga is **1555200000** days, that of Lunar yuga is **1603000080**, of Solar yuga is **1577917800** and of Sidereal yuga is **1732600080.**"

षद् प्राणास्तु विनाडी, तत्षष्टया नाडिका, दिनं षष्टया ।।
एतासां त्रिंशन्मासस्तैर्द्वाशिभिरब्दः ।।

"Six 'praṇas' make a 'vināḍī', sixty vināḍīs make a nāḍikā (or ghaṭikā), sixty nāḍikās make a day; thirty such days make a month and twelve months make a year."

षष्टयातु तत्पराणां विकला, तत्षष्टिरपि कला. तासां ।।
षष्टयांशस्ते त्रिंशद्राशिस्ते द्वादश भचक्रं ।।

"Sixty 'tatpars' make a 'Vikalā', sixty 'vikalās' make a 'kalā' (minute), sixty 'kalās' make an '*aṃśa*' (degree), thirty degrees make a rāśi (sign) and twelve rāśis make a 'Bhacakra' (Zodiacal circuit)."

चांद्रैः सावनवियुतैः प्रचय (४७८००००८०) स्तैरपचयोर्कदिनैः (२५०८२२८०)
युगवत्सरैः प्रयच्छति यदिमानचतुष्टयं किमेकेन ।।
यदवाप्तं ते दिवसा विज्ञेयाः साबनादीनां ।।

"We get the number of suppressed days with the help of the number of solar days in the yuga and the difference (47800080) between the measures of the lunar and sāvana yugas. When all the four results can be obtained by means of the above figures, where is the need of remembering the results individually ? Whatever results we thus obtain, indicate the number of days in the Sāvana and other kinds of Yugas."

वेदाश्विवसुरसांतरलोचनदस्रै (२२९६८२४) खनिसूनु: ॥
अंबरगगनवियन्मुनिगुणविवरनगेंदुभि: (१७९३७०००) शशिसुतस्य ॥
आकाशलोचनेक्षणसमुद्रषटकानलै (३६४२२०) जींव: ॥
अष्टवसुहुतवहानल (?) यमखनगै (७०२२३८८) भर्गिवस्यापि ॥
कृतरसशरर्तुमनुभि: (१४६५६४) सौरो; बुधभार्गवौ दिबाकरवत् ॥

"These verses give the number of revolutions which each planet makes in a yuga. Mars makes **2296824** ; Mercury's epicycle 17937000 ; Jupiter, **364220**; Venus's epicycle, **7022388** ; Saturn **146564** ; Mercury and Venus make revolutions equal to those of the Sun. "Atha kakṣāmānāni":—Now are given the lengths of the orbits of planets :—

अथकक्षामानानि-आकाशशुन्यतिथिगुणदहनसमुद्रैर्बुधार्कशुक्राणां (४३३१५००)
इंदो: सहस्रगुणितै: समुद्रनेत्राग्निभिश्च (३२४०००) स्यात् ॥
भूसूनोर्मुनिरामछिद्रर्तुसमुद्रशशिवसुभि: (८१४६९३७) ॥
रुद्रयमाग्निचतुष्कव्योमशशांकै (१०४३२११) बुंधोच्चस्य ॥
जीवस्य वेदषट्कस्वरबिषयनगाग्निशीतकिरणार्यै: (५१३७५७६४) ॥
शुक्रोच्चस्य यमानलषट्कसमुद्रर्तुरसदस्रै: (२६६४६३२) ॥
भगणोर्कजस्य नवशिखिमुनींदुनगषटकभुनिसूर्यै: (१२७६७१७३९)
रविखवियन्नववसुनवविषयेक्षण (२५९८९००१२) योजनैर्भकक्षाया: ॥

"The lengths of planetary orbits in yojanas (i.e. 8 miles) are as follows :— Mercury, Venus and the Sun, **4331500** ; Moon, **324000** ; Mars, 8146937 ; Mercury's aphelion, 1043211 ; Jupiter 51375764 ; Aphelion of Venus **2664632** ; **Saturn 127671739** ; Zodiac **259890012**".

इष्टग्रहकक्षाभ्यो यल्लब्धं चंद्रकक्षया भक्त्वा ॥
ता मध्यमा ग्रहाणां सौरादीनां कलाश्चांद्रा: ॥
पंचदशाहतयोंजनसंख्या तत्संगुणोर्धविष्कंभ: ॥
योजनकर्णार्धस्याद्भूयोजनकर्णबिधिना वा ॥

"Whatever is obtained after dividing the planet's orbital length by the moon's orbital length, is to be known as the planet's mean distance in lunar-minutes of arc. When this number is multiplied by 15, it gives the semi-diameter of the planet's orbit, which represents the planet's geocentric distance. This can otherwise be calculated from the geocentric radius of the orbit of the heavens (i.e. that of the celestial sphere)."

वसुमुनिगुणांतराष्टकषट्के (६८९३७८) दिननाथशुक्रसौम्यानां ॥
द्वादशदलषद्कोंद्रियशशांकभूतै (५१५६६) रजनिकर्तु: ॥

दस्राब्धिषद्करसनलोचनचंद्रै (१२९६६४२) खनिसूनोः ॥
रूपाग्निशून्यषट्काष्टिसंमितः (१६६२३१) स्याद्बुधोच्चस्य ॥
अष्टकवसुरसषण्मुनिशशांकवसुभिस्तु (८१७६६८८) जीवस्य ॥
वसुवसुशून्याष्टद्विकवेदै (४२८०८८) रपि भार्गवोच्चस्य ॥
एकार्णवार्थनवशशिदहनखदस्रै (२०३१९५४१) रविसुतस्य ॥
त्रिवसुरसद्विरसानलशशिवेदै (४१३६२६८३) रार्क्षपरिधिकर्णार्धं ॥

"The semidiameters of planetary orbits in yojanas are given below :— **689378** *of the Sun,* Venus and Mercury, **51566** of the Moon ; **1296642** of Mars, 166231 of Mercury's aphelion ; 8176688 of Jupiter, 428088 of Venus's aphelion, 20319541 of Saturn and 41362683 of the Zodiacal belt".

वृत्ता चक्रवदवनिस्तमसस्पारे विनिर्मिता धात्रा ॥ पंचमहाभूतमया तन्मध्ये मेरुरमराणां
तस्योपरि ध्रुबः खे न द्वंद्वं पवनरश्मिमिक्ष्चक्रं ॥ पवनाक्षिप्तं भानामुदयास्तमयं परिभ्रमति ।
सर्वेजयिन उदक्स्था दक्षिणदिक्स्थो जयी शुक्रः ॥

"Beyond darkness has been created by God Brahmā, this earth, round like wheel, was made up of five main elements. In its centre stands the mountain Meru, the abode of gods, and the pole occupies a place in the sky just above it. The wheel of stars, being propelled by wind, and creating rises and sets, revolves, as if pulled by 'reins' of wind. (The words 'na dwandwan' are not clear). All planets when occupying the north give success and only Venus, when in the south gives success."

Although the Pañcasiddhāntikā does not explicitly state that the Puliśa Siddhānta in it postulated the Yugādi system, it appears from the couplets, which mention the intercalary months and suppressed tithis, that it did not postulate the Yuga system. Moreover Brahmagupta has blamed only Romaka on that account. This tends to show that the Puliśa Siddhānta of the Pañcasiddhāntikā did probably contain the description of the yuga-system. The Puliśa's statement as quoted by Utpala includes it. The 'sāvana māna' (i.e. civil measure) alluded to in the statement is termed as 'solar' in other works, and the solar measures in the former are termed sāvana by the latter. The measures of 'bhagaṇas' etc., as quoted by Utpala from the Puliśa Siddhānta, taking the meanings of the words 'sāvana' etc. as given by other works are given below :—

Revolutions of stars	1582237800
Revolutions of *the sun*	4320000
Sāvana days	1577917800
Revolutions of the moon	57753336
Revolutions of Moon's apogee (from Beruṇī) . .	488219
Revolutions of Moon's asc. node (from Beruṇī) . .	232226
Revolutions of Mars	2296824
Revolutions of Mercury's epicycle	17937000*
Revolutions of Jupiter	364220

***This is the number of the planets' conjunctions with the Sun.**

Revolutions of Venus's epicycle	7022388
Revolutions of Saturn	146564
Civil Months	51840000
Intercalary months	1593336
Lunar months	53433336
Tithis	1603000080
Suppressed days	25082280
The Length of a year	365^{d}-15^{gh}-31^{p}-30^{vp}

This shows that the length of the year as given by the Puliśa Siddhānta of the Pañcasiddhāntikā and the Puliśa Siddhānta of Utpala are different. Thie means that the Puliśa Siddhānta of the Pañcasiddhāntikā is quite differenn from the Puliśa Siddhānta of Utpala. One more surprising fact is that Utpala himself has given the sentence as an 'extract' from the original Puliśa Siddhānta :—

खखाष्टमुनिरामाश्विनेत्राष्टशररात्रिपाः (१५८२२३७८००) ।।

भानां चतुर्युगेनैते परिवर्ताः प्रकीर्तिताः ।।

"The number of revolutions of the stars in one Caturyuga (Mahāyuga) is 1582237800."

It gives the number of revolutions of nakṣatras in a Mahāyuga. This tallies with the one mentioned in the couplets quoted above. Even then, Utpala has mentioned this as a quotation from the original Puliśa Siddhānta, and it is composed in the Anuṣṭup meter. This shows that there existed at the time of Utpala (śaka 888) two Puliśa Siddhāntas which were different from the one belonging to the Pañcasiddhāntikā group. Hence, the number of Puliśa Siddhāntas comes to be three. The first two couplets of the last 2½, out of those quoted by Utpala, describes the Universe in the manner in which it is found described in the modern Sūrya Siddhānta and other Siddhāntas ; the last half couplet refers to the conjunctions of planets. This shows that the Puliśa Siddhānta, composed in the Āryāmetre and existing in Utpala's time, must have been a complete work like other Siddhāntas. Similarly, the Puliśa Siddhānta belonging to the Pañcasiddhāntikā group also appears to have been a complete work from the detailed information cited from it above.

The numbers of revolutions and other elements in the Puliśa Siddhānta a quoted by Utpala, exactly tally with those of the Sūrya Siddhānta belonging, to the Pañcasiddhāntikā and given on a subsequent page. Similarly, all the measures, excepting the number of civil days and the numbers depending upon it, such as suppressed tithis etc. and the revolutions of Mercury and Jupiter agree with those given by First Āryabhaṭa.

Albiruṇī, the famous Muslim scholar and traveller, who had come to India with Mahmud of Ghazni, and stayed here from 1017 to 1030 A.D. and studied Indian sciences, particularly, the science of astronomy very critically remarks that the Puliśa-Siddhānta was compiled by Paulus-ul-Yunani or Paulus, the Greek, which means that the Hindus compiled it with the help of his work. Weber says that Albiruṇī could get in India only the Brahmagupta and the Puliśa Siddhāntas and none others.

Albiruṇī's statement cannot be further considered unless it is known as to which of the three Puliśa Siddhāntas referred to above was obtained by him and unless it is possible to see which of the three Siddhāntas agree with the work of *Paulus Greek*, if it be available at all now, so far as the elements are concerned. Weber observes : " A work of *Paulus Alexandricus* is available at present ; but it is not devoted to astronomy but to astrology, and hence, the elements given by the Puliśa Siddhānta do not tally with those given by it. It, however, contains some of the technical terms pertaining to the Hindu astronomy". But Weber's remark does not make it clear what terms have been used and in what contest. It seems, the work of Paulus on astronomy is not available now, and it would not be correct to draw any inference without obtaining the actual work.

References to the Puliśa Siddahānta have occurred at three or four places in the Brahma Siddhānta mentioned by Śākalya which shows that the Puliśa Siddhānta existed at the time of its compilation, but which Puliśa Siddhānta it was, cannot be said. The commentary on Brahma Siddhānta by Pṛthūdaka (Śaka 900) gives a couplet preceded by the words "deśāntararekhāca pauliśe paṭhyate" देशांतररेखा च पौलिशे पठ्यते—(meaning, the subject of terrestrial longitudes is to be read from Pauliśa*). This shows that there existed in his time a Puliśa Siddhānta compiled in Āryā-metre.

SŪRYA SIDDHĀNTA

The Pañcasiddhāntikā gives a different method for each of the five siddhāntas as far as the calculation of the sun and the moon is concerned ; but the calculation of the planets is given as from the Sūrya Siddhānta only, and this shows that the Sūrya Siddhānta was given the greatest importance. That "the Sūrya Siddhānta is the most accurate of all" has already been declared at the outset in the fourth couplet ; and it appears to have received such great importance because of its correctness when compared with actual positions in the heavens.

The 14th couplet of the Pañcasiddhāntikā states the number of intercalary months and other items as given by the Sūrya Siddhānta. The 26th couplet of the 9th chapter and all the Seven couplets of the 10th chapter, explain the methods of calculating (the places of) the sun, the moon and of eclipses etc. All the six couplets from the 11th chapter appear to give the explanation of only the eclipses as given by the Sūrya Siddhānta itself, and all the 27 couplets from the 16th chapter deal with the mean places of Mars and other planets, and the method of finding their true places, the question of retrograde and direct motions, the rising and setting etc.

In the beginning, the author quotes the couplets which mention the number of the intercalary months and other things, the revolutions of the sun, the moon and other planets and mean positions for the epoch assumed by the 'Karaṇa' work according to the Sūrya Siddhānta and these are followed by the results calculated therefrom †—

वर्षायुते धृतिघ्ने १८०००० नववसुगुणरसरसा: ६६३८९ स्युर्धिमासा: ॥
सावित्रे शरनवखेंद्रियार्णवाशा १०४५०९५ स्तिथिप्रलया: ॥ १४ ॥

अध्याय १

*See, commentary on Chapter 1.

†The original copy of the Pañcasiddhāntikā is very inaccurate. The author has quoted here the couplets, corrected by him on the basis of the underlying theory and given in the form in which they must have undoubtedly been originally compiled.

द्युगणेऽर्कोऽष्टशत ८०० घ्ने विपक्षवेदार्णवे ४४२ र्कसिद्धांते ॥
स्वरखा-च्चिवह्निनवयमी २९२२०७ हृते क्रमाद्दिनदलेऽवंत्यां ॥ १ ॥
नवशतसहस्र ९००००० गुणिते स्वरैकपक्षांबरस्वरर्नू ६७०२१७ ने ॥
षट्व्योमेंद्रियनेववसुविषयजिनै २४५८९९९६ र्भाजिते चंद्रः ॥ २ ॥
नवशत ९०० गुणिने दद्यादसविषयगुणांबरर्तुयमपक्षान् २२६०३५३ ॥
नववसुसप्ताष्टांबरनवाश्चि २९०८७८९ भक्ते शशांकोच्चं ॥ ३ ॥
शशिविषय ५१ घ्नानींदोः खार्काग्नि ३१२० हृतानि मंडलानि ऋणं ॥
स्वोच्चे दि १० घ्नानि धनं स्वरदस्रयमो २२७ हृते विकलाः ॥ ४ ॥

अध्याय ९

"Chap. 1, (14) According to the Saura (Siddhānta) there are in 180000 years 66389 intercalary months and 1045095 suppressed lunar days.

Chapter 9—(1) According to the Sūrya Siddhānta the mean place of the sun is found (i.e. in revolutions and signs etc.) by multiplying the ahargaṇa by 800, deducting 442, and dividing by 292207 successively; the place so found is for the midday at Avantī.

(2) Multiply the ahargaṇa by 900000, deduct 670217 and divide by 24589996; tne result is the mean place of the moon.

(3) Multiply the ahargaṇa by 900, add 2260353, and divide by 2908789; the result is the place of the moon's *Ucca*.

(4) Multiply the revolutiors of the moon by 51 and divide by 3120; deduct the result taken as secords. Also, multiply the revolutions of the moon's *Ucca* by 10 and divide by 227; the resulting seconds are to be added to the moon's *Ucca*."

एष निशार्धेऽवंत्यां ताराग्रहणेऽर्कसिद्धांते ॥ तत्रेंदुपुत्रशुक्रौ तुल्यगतौ मध्यमार्केण ॥ १ ॥
जीवस्य शता १०० भ्यस्तं द्वित्रियमाग्निनित्रसागरै ४३३२३२ र्विभजेत् ॥
द्युगणं कुजस्य चंद्रा १ हतं तु सप्ताष्टषड् ६८७ भक्तं ॥ २ ॥
सौरस्य सहस्र १००० गुणं ऋतुरसशून्यर्तुषद्कमुनिखैकैः १०७६६०६६ ॥
यल्लब्धं ते भगणाः शेषा मध्याग्रहाः क्रमेणैव ॥ ३ ॥
राशिचतुष्टय ४ मंशद्वयं २ कलाविंशतिर्वसुसमेताः २८ ॥
नववेदा ४९ श्च विलिप्ताः शनेर्धनं मध्यमस्यैवं ॥ ५ ॥
अष्टौ ८ भागालिप्तर्तवः ६ खमक्षी २० गुरौ विलिप्ताश्च ॥
क्षेपः कुजस्य यम २ तिथि १५ पंचत्रिंशच्च ३५ राश्याद्यः ॥ ६ ॥
शत १०० गुणितं बुधशीघ्रं खरनवसप्ताष्टभाजिते ८७९७ क्रमशः ॥
अत्रार्धपंचमा ४।३० स्तत्पराश्च भगणाहताः क्षेप्याः ॥ ७ ॥
सितशीघ्रं दश १० गुणिते द्युगणे भक्ते स्वरार्णवाश्वियमैः २२४७ ॥
अर्धैकादश देया विलिप्तिका भगणसंगुणिताः ॥ ८ ॥

सिंहस्य वसुयमांशा: २८ खरेंदवो १७ लिप्तिका ज्ञशीघ्रधनं ॥
शोध्या: सितस्य बिकला: शशिरसनवपक्षगुणदहना: ३३२९६१ ॥ ९ ॥

अध्याय १६.

"(1) The determination of the mean places of the smaller planets for midnight at Avantī is, according to the Sūrya Siddhānta, as follows :— Mercury and Venus have the same motion as the mean sun.

(2) For Jupiter, multiply the ahargaṇa by 100 and divide by 433232. For Mars multiply the ahargaṇa by one and divide by 687.

(3) For Saturn, multiply the ahargaṇa by 1000 and divide by 10766066 The quotients are the entire revolutions ; from the remainders, the mean places of the planets are ascertained in signs, degrees and so on.

(4) For each revolution of Jupiter 10 'tatparas' (i.e. sixtieth parts of seconds) have to be deducted. 14 'tatparas' are to be added for each revolution of Mars ; five have to be deducted for each revolution of Saturn.

(5) Four signs, two degrees, twenty-eight minutes and forty-nine seconds have to be added to the mean place of Saturn.

(6) Eight degrees, six minutes and twenty seconds constitute the additive quantity for Jupiter. For Mars that quantity amounts to two signs fifteen degrees and thirty-five minutes.

(7) For the 'śighra' of Mercury, multiply the ahargaṇa by 100, and divide by 8797. Add the product of the completed revolutions, and four and a half 'tatparas'.

(8) For the 'śighra' of Venus, multiply the ahargaṇa by 10 and divide by 2247. Add ten and a half seconds, multiplied by the revolutions.

(9) Twenty eight degrees of Leo (i.e. 4 signs plus 28 degrees) and seven teen minutes are the additive quantity for the 'śighra' of Mercury. From the 'śighra' of Venus 332961 seconds are to be deducted".

The first two couplets above give 365d-15gh-31pal-30vip as the measure of the year, and assuming the Kaliyuga to have commenced on Thursday, at midnight (when the longitudes of the sun and the moon were *nil*), the mean. Sun's entry into Aries in *Śaka* 427 falls on Sunday, the 14th tithi of Caitra, dark-half at 48gh-9pal. (The mean longitude of the sun was zero at the moment). The couplet "dyugaṇerko...." gives $11^s 29° 27' 20''$ as the mean position of the sun at the epoch, and the couplet clearly states it to be true for the noon at Avantī, but what day it refers to is not stated therein. The mean longitude of the sun for the noon of Sunday, the 14th tithi of Caitra, dark half, as calculated for the moment 33gh-9p, before the mean sun's entry into Aries, tallies exactly with the epochal position given. This shows that the Sūrya Siddhānta of the Pañcasiddhāntikā has assumed the commencement

of the yuga at midnight and that it postulates the Yuga system. These conclusions prove* to be true from the fact that the figures for the revolutions of planets as giver below agree with the planetary positions calculated on the assumption of the beginning of the Kali yuga at midnight.

The figures as calculated from the Couplets quotea above are as follows —

	d	gh	pal	vipal
The length of the year	365—	15—	31—	30

In a Mahāyuga (*i.e.* **4320000** *years*)

The No. of revolutions of		The No. of revolutions of	
The stars . . .	1582237800	Jupiter	364220
The Sun . . .	4320000	Venus . . .	7022388
Sāvana days . . .	1577917800	Saturn . . .	146564
Moon's revolutions .	57753336	Solar months . .	51840000
Revolutions of Moon's apogee	488219	Intercalary months .	1593336
Moon's asc. node . . .	..	Lunar months . .	53433336
Revolutions of Mars . .	2296824	Tithis . . .	1603000080
Revolutions of Mercury .	17937000	Suppressed days .	25082280

The epochal positions as 'emerging' from the above couplets (i.e. the positions at the epoch, calculated on the basis of the Sūrya-Siddhānta of Pañcasiddhāntikā) are as follows :—

	s	°	′	″	
Sun . . .	11	29	27	20	These positions are true for the noon of Sunday, the 14th tithi of the dark half of Caitra, śaka 427 (elapsed).
Moon . . .	11	20	11	16	
Moon's Apogee .	9	9	44	53	

*Assuming at first that the yuga commenced on Thursday at midnight and adjusting planetary positions true for the moment, and then, arguing on the basis of the agreement of the two that the assumption was correct, appear like "arguing in a circle". But one is forced to follow this method in the case of many problems in astronomy when nothing certain is known about them in the beginning. I have stated above only the final results obtained after the full consideration of the facts embodied in the above couplets. But only experienced persons can realize what pains I must have had to take over before arriving at the conclusion, and in how many ways I had to make different assumptions and to attempt the verification of their truth. When in August 1887 and Feb. 1888, inspite of several difficultes enumerated below, I could establish a correspondence between the multipliers and divisors with the epochal elements, and could particularly explain how the planetary positions mentioned by the Bhāswat karaṇa and Khaṇḍakhādyaka almost agree with the figures given by the Sūrya,Siddhānta of the Pañcasiddhāntikā, and could establish a certainty about the three works, my delight knew no bounds. The difficulties were (i) the Pañcasiddhāntikā was compiled about 1400 years ago (ii) it had no commentary, (iii) the copy which I had obtained was very inaccurate (iv) suspicion about the reliability of the words denoting the numerical quantities indicated by them and written below, in the above couplets, since the manuscript was incorrect, and (v) the fact that the figures indicating the length of the year and revolutions of planets do not fully agree with any of the modern siddhāntas. It must, however, be recorded here that this research does not deserve any more importance than what it is worth from the historical point of view. I enjoyed some more such moments of delight while writing this work—The author.

	s	°	′	″
Moon's asc. node	..	..	..	..
Mars	2	15	35	4
Mercury	4	28	17	7
Jupiter	0	8	6	20
Venus	8	27	30	35
Saturn	4	2	28	49

The epochal positions of Mars and other planets are true for the midnight of Sunday, the 14th tithi of the dark half of Caitra.

The motion and position of Rāhu (moon's asc. node) has been mentioned in the 5th couplet of the 9th Chapter, but the couplet is unintelligible. The first couplet of the 16th Chapter clearly states that the epochal positions are true for the midnight, but which day it refers to has not been mentioned. The positions of planets, calculated on the basis of planetary revolutions mentioned above and true for the midnight of Sunday, the 14th tithi of the dark-half of Caitra, i.e. a moment 3gh-9 palas before the mean Sun's entry into Aries, completely agree with the epochal positions given by the couplets. The 6th couplet gives the 'kṣepakas' (epochal positions) for Mars, and the figures for seconds (of arc) appear to have been left out from it. The 9th couplet mentions Mercury's positions which contain no figures for seconds ; and the position of Venus is given shorter by four seconds. But there would be no harm if it be said tnat the difference of a few seconds in the epochal positions should be regarded as negligible.

The above mentioned figures denoting revolutions and the length of a year do not agree with the corresponding measures of revolutions etc. given by the modern Sūrya Siddhānta. This shows that the Sūrya Siddhānta of Pañcasiddhāntikā and the modern Sūrya Siddhānta differ from each other in respect of elements and revolutions etc. That the former is older than the latter is evident from the fact that Varāhamihira has incorporated only the former. The date of the latter will be considered later on.

The above figures from the Sūrya Siddhānta of the Pañcasiddhāntikā completely agree with those from the Puliśa Siddhānta and cited from Utpala above. It will be shown later on that Brahmagupta has adopted in his work, "Khaṇḍakhādyaka", all these elements except those for the Moon's Apogee and the Ascending Node. It will be seen that all the elements from the Sūrya Siddhānta of the Pañcasiddhāntikā, except those for the length of the year and the revolutions of Mercury and Jupiter, completely agree with those of the Siddhānta of Āryabhaṭa which are given later on. It will be shown*

*Jupiter's 'Kṣepaka' (epochal position) as given by Bhāsvatīkaraṇa agrees with the calculated result, if 364224 be assumed as the Jupiter's bhagaṇas (revolutions) instead of 364220 ; but this (364220) can be proved to be the Jupiter's 'bhagaṇas' according to Pañcasiddhāntikā, from the multipliers and divisors, as mentioned in the first half of the 2nd couplet of the 16th Chapter, given above. Accepting 364224 as the correct number, 100 revolutions require 433227 days. Utpala's Puliśa Siddhānta and the modern Sūrya Siddhānta give 364220 as the number of Jupiter's revolutions and on the basis of this very number one can arrive at the Jupiter's 'Kṣepaka' according to Khaṇḍakhādyaka. The Siddhānta of Āryābhaṭa states 364224 to be Jupiter's bhagaṇa ; and Varāoamihira, while describing in the 8th chapter of Bṛhatsaṃhitā, the method of finding the 'Barhaspatyasamvatrsa' (Jovian year) for any śaka year, assumes a Kṣepaka which can be obtained by assuming 364224 as the Jupiter's bhagaṇa.

further, that the mean planetary positions for the epoch, have been obtained from the Bhāsvatīkaraṇa, by borrowing from the Sūrya Siddhānta of Pañcasiddhāntikā, the elements for all planets, except Jupiter, and applying the corrections suggested by Varāhamihira separately, in the 10th and 11th couplets of the 16th Chapter of the Pañcasiddhāntikā.

Albiruṇī states† that the Sūrya Siddhānta was compiled by Lāṭa ; but, the Sūrya Siddhānta of the Pañcasiddhāntikā is not compiled by Lāṭa. Prof. Weber says‡ that the Sūrya Siddhānta must have some connection with Ptolemy. Both these points will be discussed later on in the course of the study of the modern Sūryasiddhānta.

The above study of the five Siddhāntas, includes that of their dates also. They are, Paitāmaha, Vāsiṣṭha, Pauliśa, Saura, and Romaka as seen in their chronological order. It seems that Romaka belongs to a pre Śaka period and the remaining four were older than it.

THE PAURUṢA (HUMAN) AUTHORS OF ASTRONOMICAL WORKS BEFORE ŚAKA 420

The Pañcasiddhāntikā mentions names of some authors of astronomical works and no other source than this is available for obtaining any information about authors or writers of works before Śaka 420.

The followirg references are found in the Pañcasiddhāntikā—

पंचम्यो द्वावाद्यौ (पौलिशरोमकसिद्धांतौ) व्याख्यातौ लाटदेवेन ॥ ३ ॥

अ० १.

लाटाचार्येणोक्तो यवनपुरे चास्तगे सूर्ये ॥ रव्युदये लंकायां सिंहाचार्येण दिनगणोभिहितः ॥ ४४ ॥

यवनानां निशि दशभिर्गतैर्मुहूर्तैश्च तद्गुरुणा ॥ लंकार्धरात्रसमये दिनप्रवृत्तिं जगाद चार्यभटः ॥

४५ ॥

भूयः स एव सूर्योदयात् प्रभृत्याह लंकायां ॥

अ० १४.

(3) The first two of the five (viz. Pauliśa and Romaka) have been described by Lāṭadeva.

(44 & 45) The purport of these very important lines from the 14th chapter is as follows—Lāṭācārya has enjoined the calculation of ahargaṇa from the moment of sunset (on the horizon) of Yavanapur.

(The moment of sunset at Yavanapur coincides with that of midnight at Laṅkā). Siṃhācārya has enjoined the calculation of ahargaṇa from the sunrise at Laṅkā, while his preceptor enjoins the adoption of ten muhūrtas (i.e. 20 ghaṭis) in the night for the calculation of ahargaṇa in the Yavana country. Āryabhaṭa after stating the commencement of the day as from the midnight at Laṅkā, has again defined the day as begining from the sunrise* there. The name of Siṃha's preceptor referred to here is not known. Here is a reference quoting some more names :—

†See Dr. Kern's Preface to the Bṛhatsaṃhitā and page 2 of the Translation of the Sūrya Siddhānta by Burgess.

‡See page 3 of Translation of Sūrya Siddhānta by Burgess.

*Āryabhaṭa's reference of the commencement of a day at sunrise at Laṅkā will be given later on. The reference of the day commencing at midnight in Laṅkā is not found in the Āryabhaṭīya.

प्रद्युम्नो भूतनये जीवे सौरे च विजयनंदी ॥ ५६ ॥

शेवटचा अध्याय.

"Praayumna broke down in the matter of Mars and Vijayanandi in the matter of Jupiter and Saturn..................".

These are the names mentioned by the Pañcasiddhāntikā. Of these, an accourt of Āryabhaṭa will be given later on. All these rames occur in Brahmagupta's Siddnānta also. All of tnem have been criticised by Brahmagupta in some way or other. We do not come across any mertion of their merits. Tne statement that Śrīṣeṇa has adopted some elemerts from Lāṭa in his work, Romaka, has alreaay beer giver above. Varāha remarks that Lāṭa has commented upon the Puliśa ard Romaka Siddnārtas and this commentary cannot possibly contain his own views. This shows tnat Lāṭa must have compiled a separate work. Brahmagupta elsewnere observes :—

श्रीषेणविष्णुचंद्रप्रद्युम्नार्यभट्टलाटसिंहानां ॥ ग्रहणादिविसंवादात् प्रतिदिवसं सिद्धमकृतत्वं ॥
४६ ॥

†अंकचितिविजयनंदिप्रद्युम्नादीनि पादकरणानि ॥ यस्मात्तस्मात्तेषां न दूषणान्यत्र लिखितानि ॥
५८ ॥

अध्याय ११

It shows that Lāṭācārya had perhaps compiled a work. Similarly Siṃhācārya also had compiled one. Even Varāhamihira has remarked in one of the above mentioned couplets that Pradyumra broke down in respect of Mars and Vijayanandi about Jupiter and Saturn. The 'Karaṇa' works of both these authors are described as 'pādakaraṇa'. In one of the couplets given before, Brahmagupta says that Śrīṣeṇa has borrowed the Vijayanandi's pādas. This remark is unintelligible, and it is not clear if 'pāda' means a 'yugapāda'.

Anyway, it appears that Lāṭa*, Siṃhā, Pradyumna and Vijayanandi were authors of astronomical works who lived before Śaka 420.

THE FIVE MODERN SIDDHĀNTAS

(SŪRYA, SOMA, VASIṢṬHA, ROMAŚA AND ŚĀKALYA'S BRAHMA SIDDHĀNTAS)

The Pañcasiddhāntikā included all the siddhāntas excepting the Somasiddhānta, and it has already oeen showr that these siddhāntas and those which are to be corsidered now, are differert, ard this fact will be further corroborated by the discussior which will follow. The siddhārtas whose study is going to be made now are extant present and are different from those belongirg to the Pañcasiddhāntikā group ; and that is why the epithet 'modern' has been applied to them. Although there is no definite evidence to show that there existed or still exist two Somasiddhāntas, still it is completely

†The word 'aṅkaciti' also seems to be a proper noun.

*After studying the contents of Vedāṅga Jyotiṣa and the above discussion, it will be seen that there is no sense in the suspicion expressed by Weber that Lāṭa msut be the same as Lagadha.

similar to the other four, and it is desirable to study it (i.e. Somasiddhānta) along with them. After a general discussion of the five siddhāntas, each of them will be considered separately later on.

APAURUṢEYA *i.e.* DIVINE

All the five siddhāntas declare themselves to be divine and they are actually so regarded. No other siddhānta is regarded as divine except these five siddhāntas, and some or all of the siddhāntas from Pañcasiddhāntikā, and Viṣṇudharmottara Brahmasiddhānta. Even if there were some other siddhāntas regarded as divine before, they are not at present available. The Vyāsasiddhānta, Garga siddhānta, Nārada siddhānta and Parāśara siddhānta are also divine ; but these should better be called Saṃhitās than Siddhāntas. The author does not think that a work known after Vyāsa and others, and dealing with subjects usually found in siddhānta and in their usual order can be available at present ; and if there be one, he has neither seen nor read it. The number of revolutions and other elements are quoted by European scholars from the Parāśara Siddhānta ; but these are given in one of the Chapter of second Āryasiddhānta as taken from Parāśarasiddhānta. The siddhānta as an independant work is not available. This point will be considered at greater length in the study of the second Āryasiddhānta. The Brahma-siddhānta by Viṣṇudharmottara (Puraṇ) will later on be discussed at greater length. The most ancient of the 'pauruṣa' (i.e. human) siddhāntas is the first Āryasiddhānta. Its date is Śaka 421. All the siddhāntas enumerated at the top may not necessarily be more ancient than this. It is, however, felt that at least one of them must be older than that. Because all are similar to one another, and because these are also regarded as divine, it will be proper to describe them first, just after the discussion of Pañcasiddhāntikā.

At first the numbers of revolutions and other elements mentioned by all the five siddhāntas, which are the same in all the works, are given below :—

The elements given by the Sūrya, Soma, Vasiṣtha, Romaka Siddhāntas and Śākalya's Brāhma Siddhāntas :—

Years spent in Creation	17064000
Number	*In a Mahāyuga*
Revolutions of 'stars'	1582237828
Revolutions of the Sun	4320000
Sāvana days	1577917828
Revolutions of the Moon	57753336
" Moon's apogee	488203
" Moon's anomaly	57265133
" Moon's node	232238
" Mars	2296832
" Mercury	17937060
" Jupiter	364220
" Venus	7022376

Revolutions of Saturn	146568
Lunar months	53433336
Lunar tithi	1603000080
Solar months	51840000
Intercalary months	1593336
Suppressed tithis	25082252

Planet	*No. of revolutions in a Kalpa*	
	Aphelion	Node
Sun	387	..
Mars	204	214
Mercury	368	488
Jupiter	900	174
Venus	535	903
Saturn	39	60

THE YUGA SYSTEM

These give 17064000 as the number of years elapsed after Creation, and some thing must be stated about this. Some idea about the yuga system has already been giver in the Introduction. According to Brahmagupta and his followers, the creation took place at the beginning of Brahma's day, and at that moment, *i.e.* in the beginning of Kalpa, all the planets, their aphelia and nodes were conjoined together with the first point of Aries. According to Modern Sūryasiddhānta and other siddhāntas which follow it, the world was not created at the beginning of Kalpa but Brahmā required 47400 divine years that is a period equivalent to 39½ Kali yugas for creating the world. All planets, their aphelia and nodes came together when so much time elapsed after the beginning of Kalpa, and then the planets began to move. Āryabhaṭa II holds almost the same view. He, however, supposed a different number for the period elapsed in Creation, which will be mentioned later on. Similarly, the views of Āryabhaṭa I, will be given later on. We have no means to know the views of Sūrya and other Siddhāntas of the Pañcasiddhāntikā.

According to the modern Sūryasiddhānta, all planets are supposed to come together by mean motion, in the beginning of the present Kaliyuga. Similarly, all the planets were together, at the end of the Kṛtayuga when the Sūryasiddhānta was compiled. The numbers denoting revolutions of planets in a Mahāyuga are divisible by 4. Hence, each planet makes complete revoultions in a period equivalent to 2½ (*i.e.* 10÷4) Kaliyugas, and therefore, all planets will come together after each such periods of 2½ Kaliyugas. A period equal to 4567 Kaliyugas passed after the beginning of Brahma's day till the beginning of the present Kaliyuga. This number is not divisible by 2½ ; hence, all the planets cannot be shown to be together at the beginning of Kalpa unless it be assumed that some years must have been spent in creation. Supposing

that a period equal to 39½ Kaliyugas passed in creation, the period elapsed between the setting in motion of planets to the commencement of the present Kaliyuga comes to be (4567—39½=4527½) Kaliyugas. This number is divisible by 2½. Hence, after supposing that all planets were together in the beginning of creation, they will be found to be together in the beginning of the present Kaliyuga and at the end of Kṛtayuga before it. Similarly, starting with the assumed number of revolutions in a Kalpa, the aphelia and nodes will be seen to be together only in the beginning of creation and at no other time.

GENERAL DESCRIPTION

Of these five Siddhāntas, the Sūryasiddhānta is very famous. It has been commented upon by many, and it has been even printed and published. The remaining four Siddhāntas are not much known. Of them, the Vasiṣṭha siddhānta, consisting of 94 couplets in 4 Chapters, has been published by Vindhyeśvarī Prasād Śarmā of Vārānasī. No other siddhānta in printed form has come to my notice. I have, with great difficulty, procured copies of all the four siddhāntas. There is a manuscript in the Deccan College collection entitled 'Vasiṣṭhasiddhānta-Bhūgolādhyāya' which is different only in wording from the Vasiṣṭhasiddhānta published at Vārānasī, (D.C. collection No. 78 of 1869-70 A.D.). It has two chapters which contain 133 verses in all. Of them, the first chapter, consisting of 121 couplets, contains a description of the Universe as in other siddhāntas. The second chapter gives only the measures of orbital lengths. The numbers of revolutions and other elements in both the Vasiṣṭha Siddhāntas are exactly the same ; and hence it would be correct to say that there is only one Vasiṣṭha Siddhānta and not two. This point will be discussed to some extent later on.

It has no doubt been remarked above that the numbers of revolutions and other elements are the same in all the above mentioned five siddhāntas ; but a slight departure was noticed which ought to be mentioned. A manuscript copy of the printed Vasiṣṭha Siddhānta is kept in the Deccan College collection (under No. 36—1870-71) and the following couplet is found in the first Chapter :—

नृपेषु सप्तवहृय (*श्वि?) यमेभेषुघरोन्मिता: (१५८२२३७५१६). ॥
भभ्रमा: पश्चिमायां च दिशि स्युर्वै महायुगे ॥ १७ ॥

"The number of revolutions of '*stars*' in a westerly direction is 1582237516 in one Mahāyuga."

The number of sāvana days in a Mahāyuga, as deduced from the number of revolutions of '*stars*' mentioned in this couplet, prove to be 1577917516, which gives 365^{d}-15^{gh}-31^{p}-15^{vp}-48†^{vp} as the length of the year. This measure is different from that of all other Siddhāntas. But this verse is not found in the book printed in Vārānasī. Even the second version of Vasiṣṭha Siddhānta referred to above (Deccan College collection, No. 78 of 1869-70) does not give the number of revolutions of stars. Again, the Siddhāntas†, which have been mentioned by Kamalākara (S. 1580), the author of Siddhānta-tatvaviveka as being quite similar to Sūryasiddhānta include even this very Vasiṣṭha-siddhānta. It appears from this that the couplet given in the Deccan College copy is interpolated, and that is why the numbers of revolutions and other elements in the Vasiṣṭhasiddhānta have been mentioned as bearing a resemblance with those of other Siddhāntas.

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*The 8th letter is missing in this copy ; there must have been some letter denoting the number 2, and hence, I have inserted 'śvi' as the letter.

†See Chapter on "bhagaṇa māna" verse 65.

THE DATE

Let us corsider in a general way the dates of these five Siddhāntas.

Bentley has found out a method of determining the date ot compilation of a work on astronomy and from it he has fixed 1091 A.D. or Śaka 1013 as the date of the modern Sūrya Siddhānta. The method is as follows :—

To calculate the mean positions of planets with respect to the sur from the formulae given by the siddhānta whose date is to be found, and ther after comparing them with the corresponding mean positions calculated from modern European books on astronomy, to see for what date, the planetary positions, as given by the siddhānta prove to be true in the case of each planet, and then to fix up the date of the siddhānta by adopting the average date. This method appears to be correct at first sight, and there can be no mistake if we accept Bentley's assumptions. But it is wrorg to follow this method as can be seen from all considerations and the dates found out on that basis will not be reliable. The reasons are as follows :—Bentley's big mistake lies in the fact that he compared the mean places of planets calculated from the correct European tables, with those obtained from the Hindu astronomical works. But the mean planets cannot be seen in the heavens ; what is meant is that the planets will be seen to occupy those positions in the heavens which are found as true longitudes and not as mean. Whenever the Indian astronomers compiled their original works or found that the planets did not occupy places as indicated by their original works, they rectified their original works by applying suitable corrections (bījasaṃskāra)as applicable at their time. They must have done this with the help of observed positions, i.e. the places which they saw the planets actually occupying in the sky. The difference between the mean and the true place of a planet may be termed as 'phalasaṃskāra'' (equation of centre). If the value of this 'phalasaṃskāra' and the method of applyirg it be the same in the European and Hindu works, there would be no harm if the method of finding the date of a work on the basis of mean place be followed ; but it is not so. The 'phalasaṃskāra' to be given to the Sun is never less than 2° 10′ according to any Indian work while that according to the European works it is about 1° 55′ at present ; and this equation is not always the same. The authors of European works have proved that this equation was 2° 10′ at 3000 B.S. (before Śaka), but is gradually decreasing. The Moon's equation according to the Hirdu works is about 5°, while according to European works it some times comes to 8°. The equation adopted by the Hindus is very erroneous. The figures denoting equations for other planets also are somewhat different. Similarly, the methods of finding the true place from the mean place and the elements for the 'mandocca and śighrocca' (aphelia) are differert in the two kinds of works. Hence, it should not be taken to be a rule that even if the mean longitudes of planets, as calculated from the Hindu as well as the European works agree, that will result in the same figure for true place, and conversely, it cannot be said that a similar figure for the true place obtained from both will not necessarily give the same figures for the mean longitudes. Similarly, whatever difference be found in the two will not be found to follow the same law for all times to come. If under a particular case, similar values

of mean longitudes calculated from the two, be seen to yield similar figures for the true longitudes as well, they will be found to give different value in another case. For instance, if the mean and true places of Saturn, in Leo, be found to be the same figures according to both the works, it is not certain that similar results will be obtained for the Saturn in Scorpio. Hence, the variation in values of the equation of centre and that in the methods of finding them, would be found to lead to a variation of some centuries, even when the variation in the values of equations as found from the two works be very small. For instance, the following errors were noticed in the planetary position according to the modern Sūrya Siddhānta in the years noted below and as found by Bentley :—

	538 *A.D.*			1091 *A.D.*			*Correct year A.D.*
	°	′	″	°	′	″	
Moon*	—0	18	30	—0	0	11	1097
Mars	+2	26	30	+0	58	29	1458
Jupiter	—1	21	47	+0	41	14	906
Saturn	+1	50	10	—1	4	25	887

This shows that the error in the place of Mars in 538 A.D. was about 2½° and in those of others less than 2°. The error in the case of the Moon was extremely small. The places of all planets can possibly be found to be the same as the true places calculated by European tables and true for some moment during some particular revolution of those times ; that is, in other words, they can prove to be most accurate ; and hence it can be said that if the places of planets given by the Sūrya Siddhānta† agreed with those calculated from European tables for some date during the decade near about 538 A.D. ; then the Sūrya Siddhānta can be said to have been compiled about the year 538 A. D.. The compilation of original works of the Hindus or the corrections applied to them must have been based on the experience of at least 25 or 30 years ; and there are no means to know which planets were observed, on what dates and how, during this period. Hence, the method of determining of the date of compilation of a work according to Bertley's method is not faultless. Prof. Whitney has pointed out some of the drawbacks of Bentley's method, but has not pointed out the above very important and main drawback.

Bentley himself has considered the pros and cons of this method, but has not considered these objections.

Another point is that Bentley, while comparing the places of planets, has only calculated their distances from the Sun, but has not considered the error in the Sun's place as given by the Indian works, and which has crept in because of a small error in the length of the sidereal year adopted by our works. Prof. Whitney has pointed out that the consideration of this point will show that the Sun's place given by the Sūrya Siddhānta would be for the year 250 A. D. The

*When the planet's place is seen to be in advance of that obtained by European tables, the variation is indicated by plus (+) sign, and when it is behind, it is denoted by Minus (—). The error in the case of Mercury and Venus exceeded 3° and hence, the difference has not been shown here.

†It is sure that if the positions of all planets be calculated from both the works for different dates during 5, 10 or perhaps 30 years, it can be shown that the planetary places do agree for a particular date ; but the author has not done the calculation, since it involves much time and labour.

Indian authors could possibly have determined the corrections (Bījasaṃskāra)* to be applied to planets by two methods. One method of determining the correction for a planet is by observing its conjunction with stars, and the second is by observing its place by the '*Nalikā*' *instrument*. Tne lergtn of a year adopted by our works which is nearly equal to that of the sidereal year but actually exceeds it by about 8 palas and this (variation) leads to a gradually increasing error in the longitudes of stars. The error at present is about 4½ degrees. (The difference in the Paṭawardhan's almanac and other nirayaṇa almanacs is due to this fact). Hence, if the corrections were determined from the conjunction of the planet with a star, it is bound to err, because the place of the star with which the planet was conjoined, was erroneous, and the date of compilation of work found on this basis must also err. The second method is that of observing a planet by the '*nalikā*' *instrument*. These methods of observation necessitate the conversion of the planet's place irto a tropical (sāyana) form ; ard although the adopted motion for the equinox is somewhat erroreous, the correction is not likely to go very wrong because the time taken by a planet or the sun to come to equinox does not differ much. Hence, becuase the corrections have been determined by this method, the date of compilation of a work, as found by Bentley's method of comparisor of errors in planetary places with respect to the sun, can be accepted ; but tne time when the sun, accordirg to our works is found to come to the equinox, is somewhat erroneous. Because of this and also because the correction can possibly have been erroneous to the extent to which the observed results would be approximate, the date of compilation of a work car also be erroneous. The third poirt to consider is that, if it be supposed that Bentley's method is correct, it will be proper to use his method, if the author of the work, whose date is to be determined, has given the positions of planets by actual observation. But it will be of no use to apply the method, if the author has incorporated ir his work the planet's places exactly as they are given in another work. If the correction given by Bhāskarācārya in his work be set aside, the elements of revolution etc. giver by him are exactly the same as those given by Brahmaguptasiddhānta, and hence, the date of compilation of both these works will, by Bentley's method, come to be the same ; but the fact remains that Bhāskarācārya compiled his work, "Śiromaṇi", 522 years after Brahmagupta's Siddhānta. The correction given by Bhāskarācārya's work is found even in Rāja Mṛgāṅka, a work of Śaka 964. (More discussion about this will be given later on.) Hence, the dates of Rāja Mṛgāṅka (Śaka 964), Siddhānta Śiromaṇi (Śaka 1072) or of Karaṇakutūhala (Ś. 1105) will come to be the same by Bentley's method.

Bentley's method proves useless if the dates found by it are compared witn the actual dates. The author attempted to apply tne method in the case of the Sūrya Siddhānta of the Pañcasiddhāntikā and the first Āryasiddhānta and these are the inferences :—

*If it is found that the place of a planet as calculated from a Siddhānta does not agree with the observed place, it is decided to apply suitable correction to the motion and place of the planet as given by the work and this correction is known as 'Bīja'.

	The year when the planet according to Sūryasiddhānta would be correct	The year when the planet according to first Āryasiddhānta would be true
	Śaka	Śaka
Moon	520	468
Moon's apogee	482	482
Moon's asc. node	—	523
Mars	457	457
Mercury	93	734
Jupiter	772	480
Venus	409	409
Saturn	574	574
	3307÷7=472	4127÷8=516

This leads one to infer* that the Sūrya Siddhānta of Pañcasiddhārtikā was compiled in Śaka 472 and the first Ārya Siddhānta in Śaka 516. But it is beyond controversy that the first Ārya Siddhānta was compiled in Śaka 421 and it has also been shown before that the Sūrya Siddhānta of Pañcasiddhārtikā must have belonged to a period much earlier than Śaka 421. Bentley† has determined 1288 A. D. (Śaka 1210) as the date of the Ārya Siddhānta consisting of 18 chapters (i.e. the second Ārya siddhānta) and 1384 A. D. (Śaka 1306) as that of the Parāśara siddhānta ; but reference to some subjects in the second Ārya Siddhānta is found in the Siddhānta Śiromaṇi. This shows that the second Ārya Siddhānta must belong to a period earlier than Śaka 1072 A. D. and references to Parāśara Siddhānta also are found in the second Ārya Siddhānta. (More discussion about this will follow later on).

This will clearly show that the dates found by Bentley are not at all reliable and that the date of the Sūrya Siddhānta (viz. Śaka 1013) determined by Bentley is not worth considering.

Let us, therefore, independently consider the matter of dates of the five Siddhāntas.

Brahmagupta observes,

अयमेव कृतः सूर्येंदुपुलिशरोमकवसिष्टयवनाद्यैः ।। ३ ।।

अध्याय २४

"This very Siddhānta has been compiled by Sūrya, Indu, Puliśa, Romaka, Vasiṣṭha, Yavanācārya and others".

The Indu Siddhānta, mentioned in this, is the Soma Siddhānta itself. It shows that there existed a Soma Siddhānta before the time of Brahmagupta. No evidence is available to show that there existed some time before, a Soma Siddhānta, different from the Soma Siddhānta now available. No such Siddhānta is either available at present, or there is no evidence of its availability. Where then is the harm, if we say that, in the absence of any evidence

*Places of planets to be calculated from European tables have been calculated from the Keropant's Planetary Tables. If more accurate table would be followed, a variation of only 5 to 10 years may possibly occur.

†See Bentley's work (1823 A.D.) Part II, Section III.

to the contrary, the Soma Siddhānta existing in Brahmagupta's time, is the same as the modern one ? It is just possible that the Soma Siddhānta in Brahmagupta's time might have been different in size and form, than the modern Soma Siddhānta ; but both of them must be similar in the matter of numbers of revolutions and other elements etc.

It has been shown above that there existed in the time of Brahmagupta a Romaka Siddhānta by Śrīṣeṇa and a Vasiṣṭha Siddhānta by Viṣṇucandra and different from the Romaka and Vasiṣṭha Siddhāntas of the Pañcasiddhāntikā. It has also been pointed out before that the Romaka and Vasiṣṭha of the Pañcasiddhāntikā are different from the modern Romaka and Vasiṣṭha Siddhāntas. A comparison of the numbers of revolutions and other elements etc. corroborates the same fact. One is, therefore, naturally led to the inference that the Śrīṣeṇa's Romaka and Viṣṇucandra's Vasiṣṭha, available at Brahmagupta's time, are the same as the modern Romaka and Vasiṣṭha Siddhāntas and we have reasons in support of them. One of them is that there is no evidence to show that there ever existed a third set of Romaka and Vasiṣṭha Siddhāntas other than the Romaka and Vasiṣṭha Siddhāntas of the Pañcasiddhāntikā, and the modern siddhāntas of the same names nor are they available at present. The second reason is that the three couplets of Brahmagupta, quoted before on page 7, giving the basis on which Śrīṣeṇa compiled his Romaka and Viṣṇucandra his Vasiṣṭha, show that both of them appear to be similar ; that is the numbers of revolutions and other elements etc. in both must be the same. The third reason is that Brahmagupta remarks that 'Viṣṇucandra has compiled the second Vasiṣṭha siddhānta.' The following couplet* is found in that version of the modern Vasiṣṭha Siddhānta which is printed at Vārāṇasī :—

इत्थं मांडव्य संक्षेपादुक्तं शास्त्रं मयोदितं ।।
विस्तृतिर्विष्णुचंद्राद्यैर्भविष्यति युगेयुगे ।। ८० ।।

"Oh Māṇḍavya ! This science has thus been described by me in brief. It will be expanded by Viṣṇucandra and others, as yugas will roll by".

This is addressed to Māṇḍavya by Vasiṣṭha and it shows that Viṣṇucandra has been associated with this. Viṣṇucandra's name has been anyhow brought in. This clearly shows that, if it is not the one actually compiled by Viṣṇucandra, it must have been written out by some one else, after borrowing Viṣṇucandra's elements. It has been mentioned in the above couplets of Brahmagupta, concerning the Romaka Siddhānta, that the Romaka has been compiled with the help of Lāṭa, Vasiṣṭha and Vijayanandi ; and the modern Romaka Siddhānta contains the following lines in the beginning :—

वसिष्टो† रोमशमुनिः कालज्ञानाय तत्वतः ।। उपवासं ब्रह्मचर्यं प्रागेकं विष्णुतत्परौ ।। २ ।।
वसिष्टसदभिप्रायं ज्ञात्वापि मधुसूदनः ।। अर्पयामास तत्सिध्यै तावच्छास्त्रार्थपारगः ।। ३ ।।
उभाभ्यां तोषितो विष्णुर्योगोयं तन्मुखद्वयात् ।। उच्चारयामास...... ।। ४ ।।

(The general sense is as follows) :

Once upon a time Vasiṣṭha and sage Romaka, started a penance, in celibate condition, invoking the favour of God Viṣṇu, for obtaining the knowledge of

*This verse is found also in the copy of the Deccan College collection ; but its latter half begins with "Vistṛtiścecca Candrādyaiḥ" which appears to be a mistake.

†We come across versions like Lomaśa for Romaśa, 'tadabhiprāyam' for 'sadabhiprāyam etc. Even the name of the siddhānta is found as Romaka and Romaśa, in two ways.

time (principles of science of astronomy). God Madhusūdana who is proficient in this science, appreciating the good motives of Vasiṣṭha and being pleased with them both, gave them away the science, as a reward for penance. He uttered the words of Science through the two mouths (Vasiṣṭha and Romaka).

Even though these contain certain errors, the verses show that Romaka and Vasiṣṭha are both associated with the modern Romaka Siddhānta. The Romaka Siddhānta existing at the time of Brahmagupta had definitely a support from Vasiṣṭha (siddhānta). Hence, an inference can be drawn that Śrīṣeṇa's Romaka and Viṣṇucandra's Vasiṣṭha, existing in the time of Brahmagupta, are the same as the modern Romaśa and Vasiṣṭha Siddhāntas. The modern Romaśa Siddhānta does not mention Śrīṣeṇa's name and the name of the Siddhānta has been maintained, through an imaginary sage Romaśa. It, therefore, seems probable that the modern Romaka may be different from Śrīṣeṇa's Romaka in respect of its wording, still the revolutions and other elements must have been the same in both.

If it be admitted that there existed before Brahmagupta (Śaka 550) Siddhāntas which were either completely similar or similar in respect of the numbers of revolutions and other elements to the Soma, Romaśa and Vasiṣṭha etc. how can it be said that the modern Sūrya Siddhānta, which resembles these three in respect of elements and which is commanding a greater reverence and importance at present than these three could not have existed before Brahmagupta's time ? The modern Sūrya Siddhānta or the Soma, Romaka and Vasiṣṭha, have no similarity with respect to elements with the first Ārya Siddhānta, which existed before Brahmagupta, and with any of the earlier five Siddhāntas of the Pañcasiddhāntikā. It has already been shown above that Lāṭācārya had compiled a work quite independently ; and according to Brahmagupta's remarks, the figures for the mean places* of all planets in Śrīṣeṇa's Romaka and Viṣṇucandra's Vasiṣṭha had been borrowed from Lāṭ 's work. It appears from this that it was only Lāṭācārya's work which was similar to modern Soma, Vasiṣṭha and Romaka, out of those, which existed before Brahmagupta's time. This fact, which emerges from the above considerations, when weighed together with Albiruṇī's statement that Sūrya Siddhānta was compiled by Lāṭa, lead one to draw the definite conclusion that, the mean places of planets i.e. and the numbers of revolutions and other elements in the modern Sūrya Siddhānta, have been taken from Lāṭācārya's works and Lāṭa lived before Varāhamihira (Śaka 427). Hence, it is the author's opinion that the elements in the modern Sūrya Siddānta belong to a period prior to Śaka 427. Even if the modern Sūrya Siddhānta is not supposed to have been compiled by Lāṭa, the modern Soma, Romaka and Vasiṣṭha Siddhāntas definitely existed before Brahmagupta's time ; and the modern Sūrya Siddhānta is much more revered and regarded as important than any of these three. This shows that the modern Sūrya Siddhānta existed before the three Siddhāntas and hence, the date of its compilation cannot be later than the 5th century of Śaka era.

Let us now consider the five Siddhāntas separately and in greater details.

*Colebrooke interpretes the words as "Mars and other planets were taken from Vasiṣṭha" But considering all facts with reference to the context, I think that the lines should be interpreted in the very way in which I have rendered them.

SŪRYA SIDDHĀNTA

Subject Matter and Date

The modern Sūrya Siddhānta has 14 Chapters. All of them together contain 500 verses in 'anuṣṭup' metre. The verses at the beginning, out of those which have given the numbers of revolutions and other elements etc. above, show that a person who was a "part of God Sun Himself" described by Sun's order, this Siddhānta to Maya, an Asura, at the end of the Kṛtayuga. It means that 2164996 years elapsed after its *revelation*, till the beginning of Śaka 1817.

An inference has been drawn above that the modern Sūrya Siddhānta was compiled by Lāṭa and hence, it must have existed in a period much earlier than Śaka 427. It, however, seems that it had not received 'Sūrya Siddhānta' as the name at the time of Varāhamihira, because the Pañcasiddhāntikā contains only one Sūrya Siddhānta, and it is different from the modern one. A reference to the Sūrya Siddhānta has occurred at two places in Bramhagupta Siddhānta. The couplets have already been given before (See page 7). We have no reasons to say that there were two Sūrya Siddhāntas at the time of Brahmagupta, and hence, it cannot be said for certain that in his time also, the modern Sūrya Siddhānta had received 'Sūrya Siddhānta' as its name ; and even if it had, it clearly appears not to have received so much importance. Because he has taken in his work, Khaṇḍakhādyaka, elements, not from his own Siddhānta or from the first Āryasiddhānta or from the modern Sūrya Siddhānta but from the Sūrya Siddhānta of the Pañcasiddhāntikā. Hence it cannot be said for certain as to when the modern Sūrya Siddhānta received the name 'Sūrya Siddhānta or inspired a feeling of reverence.' There is, however, some room for drawing an inference.

Even if the modern Sūrya Siddhānta were compiled by Lāṭa, it is not probable that all the verses in it were compiled by him. Some or almost all the remaining verses in it, except those mentioning the elements in the chapter on mean places, might have been taken from the original Sūrya Siddhānta, that is, the one belonging to the Pañcasiddhāntikā group. Otherwise, if the Lāṭa's work be not in the same form, as the present Sūrya Siddhānta, some one else must have compiled the modern Sūrya Siddhānta, by borrowing number of revolutions and other elements from Lāṭa's work and the remaining verses from the original (ancient) Sūrya Siddhānta soon after the Pañcasiddhāntikā, and two or three centuries later, it must have been an object of reverence, when the traces of its authorship were lost and forgotten.

Brahmagupta remarks (see page 8) that the Romaka and Vasiṣṭha Siddhāntas were compiled by adopting Āryabhaṭa's method of geocentric calculations of planets ; but the main elements of degrees of epicycles (paridhyaṃśa) which are so necessary for the geocentric calculations as given by Sūrya, Romaka, and others, do not agree with those of Āryabhaṭa but with the original Sūrya Siddhānta in many respects. (See the elements given in the first chapter on 'true places' later on).

The inference which follows is that either Lāṭa or whosoever be the author of the Sūrya Siddhānta, he adopted only, different numbers for revolutions and other elements etc. but borrowed the remaining items from the original Sūrya Siddhānta or retained them, word for word, as given in the original Sūrya

Siddhānta. Similarly, Brahmagupta clearly says that the elements given by Śrīṣeṇa's Romaka and those in Viṣṇucandra's Vasiṣṭha belong to Lāṭa himself. It seems that some one afterwards adjusted these Siddhānta with the original Sūrya Siddhānta in respect of principles, by omitting the remaining items which were taken from the first Āryabhaṭasiddhānta. Utpala has in his commentary on the 18th chapter of Bṛhatsaṃhitā given the following verse, preceded by "tathācācāryaḥ Viṣṇucandraḥ", meaning "so says the Ācārya Viṣṇucandra :—

दिवसकरेणास्तमयः समागमः शीतरश्मिसहितानां ॥ कुसुतादीनां युद्धं निगद्यतेऽन्योऽन्ययुक्तानां ॥

"When Mars or any other planet along with the moon, are conjoined with the Sun in a (heliacally) set condition, it is described as a fight, even when the planets are united together."

This is in *Ārya metre*, and both the versions of Vasiṣṭha Siddhāntas are in *anuṣṭup metre*. This also leads one to infer that some one must possibly have compiled the present Vasiṣṭha siddhānta on the basis of Viṣṇucandra's Vasiṣṭha Siddhānta. The same is possible about the Romaka also.

Maya

There are some annotated versions of the Sūrya Siddhānta in the Ānandāśrama, Poona, some versions contain only the text. Here the author came to know that the 7th verse in the first chapter (on mean places) in one of the books (No. 2909) without a commentary, is not found in the annotated version It stands thus together with the foregoing and following verses :

न मे तेजः सहः कश्चिदाख्यातुं नास्ति मे क्षणः ॥ मदंशपुरुषोयं ते निःशेषं कथयिष्यति ॥ ६ ॥

तस्मात् त्वं स्वां पुरीं गच्छ तत्र ज्ञानं ददामि ते । रोमके नगरे ब्रह्मशापाल्लेच्छावतारधृक् ॥ ७ ॥

इत्युक्त्वांतर्दधे देवः

(Oh Maya !) you will not be able to bear my lustre (and) I have no time to tell you (anything of the Science). This man, who is my own part, will tell you everything. Therefore, go back to your town. I will be born as a Greek (yavana) because of Brahmā's curse, in the city of Romaka. There I will initiate you in the Science. So saying God Sun vanished from sight.

This verse stands as the verse intermediate between the 6th and 7th verses in the annotated version. The 7th verse when looked taken in the light of its context appears to be altogether disconnected. This verse was found in the two versions of the Sūrya Siddhānta without a commentary and in the possession of the Rev. E. Burgess, *translator of the Sūrya Siddhānta*, but was not found in the annotated version. Whitney in his notes on the translation, has expressed his views regarding this verse as follows :—

Although it is true that this verse is clearly out of place here, between the 5th and 7th verses of the present edition, still it is found in several manuscripts of Sūrya Siddhānta and it is not probable that it has been purposely deviced and introduced. Hence, the first seven or eight verses at the beginning which are found in the present annotated edition, must have been newly inserted by some person to describe how Maya got the Sūrya Siddhānta. Originally, only the above quoted verse along with similar others, must have occupied that place ; and it shows that the Sūrya Siddhānta must have undoubtedly some connection with the Greeks in some way or the other ; not only this but the Science must have been obtained by the Hindus from the Greeks. Even

the modern Sūryasiddhānta states that the 'Sūrya Siddhānta was revealed to Mayāsura'. What was the propriety in selecting a demon (an 'asura') as the medium of revelation by the Sun ? This point also indicates an association with the Greeks.

Ptolemy

Weber says that according to Hindu inscriptions Turumaya was the name of king Ptolemaios' of Egypt. From this Asuramaya appears to have been a corruption of Turumaya, and Maya seems to be the Ptolemy* himself who was the author of the Almajest. But it has already been pointed out that Ptolemy's work has no connection with the original Sūrya Siddhānta. Similarly, the numbers of revolutions and other elements of the modern Sūrya Siddhānta given above do not at all tally with those of Ptolemy. This clearly shows that Ptolemy has absolutely no connection with the modern Sūrya Siddhānta.

A Relation between the two Sūrya Siddhāntas

Utpala's commentary on the Bṛhatsaṃhitā quotes the following verses as belonging to the Sūrya Siddhānta :—

महतश्चाप्यधःस्थस्य नित्यं भासयते रविः ॥ अर्धं शशांकबिंबस्य न द्वितीयं कथंचन ॥

तेजसां गोलकः सूर्यो ग्रहर्क्षण्यंबुगोलकाः ॥ प्रभावंतो हि दृश्यंते सूर्यरश्मिविदीपिताः ॥

विप्रकर्षं यथा याति ह्यधस्थश्चंद्रमा रवः ॥ तथा तस्य च भूदृश्यमंशं भासयते रविः ॥

अध्याय ४ चंद्रचार

भूछायां शशिकक्षागां रवौ भावां (?) तरस्थिते ॥ यदा विशत्यविक्षिप्तश्चंद्रः स्यात्तद्ग्रहस्तदा ॥

इंदुना छादितं सूर्यमधोविक्षिप्तगामिना ॥ न पश्यंति यदा लोके तदा स्याद्भास्करग्रहः ॥

तमोमयस्य तमसो रविरश्मिपलायिनः ॥ भूछाया चंद्रबिंबस्थोर्द्धं परिकल्पितः ॥

अध्याय ५ राहुचार,

"The sun illuminates half the disc (side) of the moon, even if it is occupying the lowest position (with respect to the sun) ; and the second half is never illuminated.

The sun is a sphere of lustre. The planets, the stars and particles of water shine brightly when they are illuminated by the sun.

The farther the moon goes away from the sun, while in a lower position, the greater portion of its disc becomes visible to (people on) the earth."

—*Chapter 4 on Moon's motion*

"While the sun is situated in the house opposite to that of the moon, and when the moon, having no latitude, enters that portion of the earth's shadow which intercepts the moon's orbit, the lunar eclipse takes place.

*See page 3, Translation of the Sūrya Siddhānta by Burgess. The statement of Weber has not been given above word by word, but only its summarized form.

When the sun's surface is obstructed by the moon who is passing in a downward direction and when people on the earth are unable to see the sun, then the solar eclipse takes place.

The *earth's shadow which is cast by the sun's rays, falls only on one half (Portion) of the moon's disc which is escaping from the darkness cast by Rāhu.

—Chapter 5 on Rāhu's motion.

These verses are not found in the modern Sūrya Siddhānta. It is not therefore, certain if they at all belonged to the original Sūrya-Siddhānta. If they did, it may be said that the modern Sūrya Siddhānta was not held in great reverence at the time of Bhatotpala (Śaka. 888).

Bhatotpala, in the course of his discussion of Mahākārtikādi Samvatsara, in the chapter on gurucāra, in the commentary on Bṛhatsaṃhitā, observes.

केचित्कृत्तिकादियुक्ते गुरौ यच्चंद्रयुक्तं नक्षत्रं चैत्रमासादितो भवति ततो महाकार्तिकादीनि

संवत्सराणि प्रभवादीनि च गणयंति ॥

"Some (astronomers) when they find that Jupiter has come to the star Kṛttikā, and Caitra has started, reckon the beginning of the cycle of Mahākārtikādi years and also that of the prabhava year, on the basis of the star with which they find the moon to be conjoined."

The method of naming the years of the Mahākārtikādi Series, as given in the modern Sūryasiddhānta, is as follows :—

वैशाखादिषु कृष्णे च योगः पंचदशे तिथौ ॥ कार्तिकादीनि वर्षाणि गुरोरस्तोदयात् रथा ॥ १७ ॥

मानाध्याय.

In Vaiśākha etc., a conjunction (yoga) in the dark half-month (kvṣṇa on the 15th lunnar day (tithi) determines, in like manner, the years Kārtika etc of Jupiter, from its heliacal setting (asta) and rising (udaya).

Chapter on Elements.

These two have much similarity and this method of naming the Māhakārtikādi years is found in no work other than the Sūrya Siddhānta. It cannot be kown from the Pañcasiddhāntikā if this method was given in the original Sūya Siddhānta and there is no other way to find it. If Bhaṭotpala's quotation refers to the original Sūrya Siddhānta, it would be a good means to prove that the verses from the originàl Surya Siddhanta occur also in the modern Sūrya Siddhānta.

Lāṭa

Albiruṇī, (Śaka 952 circa) says that the Sūrya Siddhānta was compiled by Lāṭa. But the original Sūrya Siddhānta in Pañcasiddhāntikā was undoutedly not compiled by Lāṭa, for had it been so, Varāha would have mentioned it and

*Different readings are found in different works and the author himself is doubtful about the words "bimbasthordhe". We come across bimbasyasthanerdhe, bimbasyordhwe etc. I have attempted to give the likey meaning—Translator.

would not have included it in the Pañcasiddhāntikā. According to Brahmagupta, the work by Lāṭa is clearly different from the Sūrya Siddhānta. He has, in addition, criticised Lāṭa's work in two or three places, but not the Sūrya Siddhānta. This shows that the Sūrya Siddhānta referred to by Albirunī as compiled by Lāṭa is not the original Sūrya Siddhānta but the modern one, and from this it appears that the importance of the Sūrya Siddhānta had been established before Śaka 952.

The author of Bhāsvatīkaraṇa declares at the outset of his work :—

अथ प्रवक्ष्ये मिहिरोपदेशात् । तत्सूर्यसिद्धांतसमं समासात् ।। ३ ।।

अधिकार २

"As instructed by Varāhamihira, I briefly compile this (Karaṇa) work which is similar to his Sūrya Siddhānta".

The words, "tatsūryasiddhānta" in this, show that there existed at the time of the author of 'Bhāswatī', a Sūrya Siddhānta different from the one incorporated by Varāhamihira in his work.

The following verses from the Sūrya Siddhānta have been given by Bhāskarācārya himself in his commentary, *vāsanā*, on Siddhānta Śiromaṇi :—

अदृश्यरूपाः कालस्य मूर्तयो भगणाश्रिताः ।। शीघ्रमंदोच्चपाताख्या ग्रहाणां गतिहेतवः ।। १ ।।
तद्वातरश्मिभिर्बद्धास्तैः सव्येतरपाणिभिः ।। प्राक्पश्चादपकृष्यंते यथासन्नं स्वदिङ्मुखं ।। २ ।।

"(1) Forms of Time of invisible shape, stationed in the *Zodiac* called the conjunction (śīghrocca), apsis (mandocca) and node (pāta) are causes of the motion of the planets."

"(2) The planets, attached to these beings by cords of air, are drawn away by them, with the right and left hand, forward or backward, according to nearness, towards their own places."

These verses are given by the modern Sūrya Siddhānta (see verses 1 and 2 in the chapter on 'true place'). Similarly, Bhāskarācārya, in the chapter on *Golabandha*, remarks about the motion of the equinox as follows :—

विषुवत्क्रांतिवलययोः संपातः क्रांतिपातः स्यात् ।।
तद्भगणाः सौरोक्ता व्यस्ता अयुतत्रयं कल्पे ।। १७ ।।

"The point of intersection of the Equator and the Ecliptic, is called '*Krāntipāta*'. The number of its revolutions in one kalpa, according to the Sūrya Siddhānta is 30000" and in his commentary of this verse, he himself says,

क्रांतिपातस्य भगणाः कल्पेऽयुतत्रयं तावत् सूर्यसिद्धांतोक्ताः ।।

Sūrya Siddhānta itself has cited 30000 as the number of revolutions of the krāntipāta in one kalpa.

This remark refers to the revolution of the zodiac mentioned in the modern Sūrya Siddhānta. Similarly the word '*arkāṃśa*' occuring in Bhāskarācārya's remark* "tasmānnedaṃ pūrvairarkāṃśādyaistathā kṛtaṃ karma" at the end of the chapter on 'solar eclipse', seems to refer to the modern Sūrya Siddhānta.

*Meaning—This calculation has not been made by former astronomers like Arkāmaśa (Incarnation of the Sun).

When held in reverence

These arguments prove that the modern Sūrya Siddhānta had achieved the position of authority and reverence before the times of Albiruṇī, Bhāsvatīkāra and Bhāskarācārya i.e. before the first half of the 10th century of Śaka era. There is no evidence available at present to show what time it was between the Śaka 550 (i.e. the time of Brahmagupta's Siddhānta) and Śaka 950.

WORKS FOLLOWING MODERN SŪRYA SIDDHĀNTA

The *Karaṇa work* written in Śaka 1220 by Vavilala Kochana of Tailangana completely follows the modern Sūrya Siddhānta. It has not found any Karaṇa work written on the lines of the modern Sūrya Siddhānta prior to this date. The Bhaṭatulyakaraṇa, written in Śaka 1339 gives the same motion for the equinoxes as that given by the modern Sūrya Siddhānta. A work called *Tājakasāra*, written in or about Śaka 1445, has come to the notice. While describing the method of calculating the planets' places, it writes,

श्रीसूर्यतुल्यात्करणोत्तमाद्वा स्पष्टा ग्रहा राजमृगांकतो वा ।।

"The true places of planets can be calculated either by the method given by Śrīsūryatulya-Karaṇa work or by the one compiled by Rājamṛgāṅka."

It shows that there existed before Śaka 1445, a Karaṇa work named *Sūrya-tulya*. The places of planets in it were, of course, taken from the Sūrya Siddhānta and they must have been from the modern one itself. The figures for the length of the year etc. cited by 'Grahakautukakaraṇa' in Śaka 1418 as having been taken from Sūrya Siddhānta belong to the modern Sūrya Siddhānta. Ganeśa Daivajña, the author of Grahalāghava, says

सौरोर्कोपि विधूच्चमंककलिकोनाब्जः ।।

ग्र० ला० मध्यमाधिकार ०

Meaning :—The elements for the sun, the moon's apogee and that for the moon diminished by 9′ have been borrowed from the Sūrya Siddhānta.

And these elements have been definitely taken from the modern Sūrya-Siddhānta. Similarly, *the tables of Tithi Cintāmaṇi* have been prepared completely from the positions of the Sun and other planets as given by the modern Sūrya-Siddhānta. (More discussion about this will appear later in the course of the comments on Grahalāghava). A commentary on Bhāswatīkaraṇa was written by Mādhava in Śaka 1442, *i.e.* in the same year in which the Grahalāghava was compiled. This commentary includes the verses, giving the revolutions of the sun, the moon, and all planets or the figures indicated in those verses. These verses and the numbers of revolutions and other elements, except those for Rāhu, completely agree with those of the modern Sūrya Siddhānta.

Makaranda is the name of a work helpful in preparing the almanac Almanacs are compiled from it in many parts of Northern India at present. The measure of the year and the numbers of revolutions and other elements for all planets have been taken by it from the modern Sūrya Siddhānta. The date of its compilation as given in the version of the Makaranda work, printed at Vārānasī, is Śaka 1400. This Śaka number has not been stated in verse

form and no other means is available in the work to prove that it is true, which leaves some room for doubt about its authenticity. Makaranda is, however, referred to by Viśvanātha and others which shows that the date may be correct. Paramādīśvara, the commentator on the Āryabhaṭīya has given 12 verses* from different chapters in the modern Sūrya Siddhānta and four of them, which are specially important, belong to the chapter on mean places, and they mention revolutions of the aphelia and nodes of all planets. The date of this Paramādīśvara is not known. The verses quoted by him from Sūrya Siddhānta are every where, preceded by the words "tathā ca Mayaḥ" meaning "so says Maya".

The work, *Tājikabhūṣaṇṇa*, was written about Śaka 1480, by Ganeśa Daivajña, son of Ḍhunḍhirāja and resident of Pārthapur (Pathāri) near river Godāvarī. He has adopted in it the length of the year as given by the original S. S. The measure for the year (viz. 365d—15gh-31p-30v) as adopted by the original Sūrya Siddhānta appears to have been in continued use till the end of the 15th century, because it was more convenient for calculation than the one (365d—15gh-31p-31v-24pv) adopted by the modern Sūrya Siddhānta.

There is a work on Muhūrta, named *Jyotiṣadarpaṇa*, which was compiled in Śaka 1479. It casually gives as an example, the ahargaṇa (*i.e.* number of days elapsed) from the beginning of creation to the beginning of Kaliyuga. Similarly, the mean places of planets for the midnight of Thursday in the beginning of Kalpa have been given in it, and they are all similar to those of modern Sūrya Siddhānta.

There is a Karaṇa-work, *Rāmavinoda* by name, compiled in Śaka 1512, which gives the length of the year according to modern Sūrya Siddhānta. Kamalākara, 1580, the author of the '*Siddhānta tatvaviveka*' is a staunch admirer of the modern Sūrya Siddhānta. The work *Vārṣikatantra*, which follows the modern Sūrya Siddhānta was written sometime between Śaka 1400 and 1634.

Commentaries

A commentary on the modern Sūrya Siddhānta entitled 'Gūḍhārthaprakāśikā' by Raṅganātha was written in Śaka 1525. An edition of Sūrya Siddhānta together with this commentary, has been printed at Vārānasī and Calcutta. A second commentary, entitled Saurabhāṣya was written by Nṛsiṃha Daivajña and belongs to Śaka 1542. A third commentary was written by Viśvanātha Daivajña and entitled 'Gahanārthaprakāśikā'. It contains examples with solutions and belongs to about Śaka 1550. A fourth commentary, written by Dādābhāī and entitled 'Kiraṇāvalī' was written in Śaka 1641. Of these four commentaries, that by Raṅganātha is more exhaustive and contains a good explanation of the theoretical aspect. Raṅganātha's commentary contains at 2 or 3 places the remark** "इति सांप्रदायिकं व्याख्यानं" meaning "this is according to tradition", and he has endorsed the views of others at 2 or 3 places with the remark† केचित् meaning "according to some". At one place is found the statement "नव्यास्तु इत्यर्थं कुर्वंति" meaning "modern†† people interpret it thus". This shows that some commentaries belonging to an earlier period were available in Raṅganātha's time. Raṅganātha has mentioned at four places, Parvata, as the name of some commentator, and has given a half-verse‡

*See verses 41 to 44 from Madhyamādhikāra ; No. 2 from Pātādhikāra, Nos. 35 to 40 from Bhūgolādhyāya and one from Mānādhikāra.

**See pages 156, 163, 201 of the Vārānasī edition.

†See pages 48, 95, 147, Vārānasi edition.

††See Vārānasī edition page 201.

‡See Varanasī edition page 212.

characterized as "नार्मदोक्त" (quoted from Nārmadā). It shows that there must have existed some mathematical work of Nārmadā in which some reference to or a corroborative statement of modern Sūrya Siddhānta could be found. In my opinion* the date of this Nārmadā must have been about Śaka 1300. Colebrooke says that there is a commentary on the Sūrya Siddhānta by Bhūdhara. Similarly, Prof. Whitney† remarks, on the basis of Wilson's catalogue, that commentaries on the whole or part of that work by Mallikārjuna, Yellayā, Āryabhaṭa, Mammabhaṭa and Tammayā, were available in the Mackenzie's Collections. A commentary by any of the two Āryabhaṭas on any of the two Siddhāntas seems to be an impossibility. Hence, there appears to be a commentary by some third Āryabhaṭa.

Bibliotheca Indica includes an English translation of the Sūrya-Siddhānta made in 1860 A. D. by Pandit Bāpūdeva Śāstrī (New series No. 1). It contains simply the translation of the text and some notes here and there. The English translation of the Sūrya Siddhānta by the Rev. Ebenezer Burgess was published by the American Oriental Society as volume VI of its Journal in 1860 ; and it has been printed in a separate volume. It was Burgess who first translated the work and added foot notes to it and Prof Whitney further added extensive notes on it. Prof. Whitney has admitted his responsibility about the views etc. expressed in these notes. It is the opinion of Prof. Whitney†† that the Hindus borrowed astronomy from the Greeks. According to Burgess on the other hand it was the Greeks who borrowed astronomy from the Hindus and this view has been expressed by him at the end of the volume.

Interpolation

Raṅganātha after giving a half-couplet in his note on the 23rd verse from the Chapter on 'conjunction of planets', has remarked that he has not commented upon the verse, since, it is found only in some works and not in all and appears to be interpolated. Similarly, after passing over 1½ couplet in the Chapter on 'elevation of moon's cusps' he has given his commentary in the next two verses and has remarked "but these appear to be disconnected and the method described therein is erroneous, they might have been interpolated by some very intelligent person who depended upon the "*Dhīvṛddhidatantra of Lalla*". He has also remarked that the four verses beginning from the 5th in the *Tripraśnādhikāra* might be regarded by some as interpolated, but it is not so ; this shows that there were in his time some persons or commentators who regarded these verses as interpolated. *Jyotiṣadarpaṇa*, a work on Muhūrta, contains about 19 verses from the chapters on mean places and on elements from the modern Sūrya Siddhānta which tally with those in the modern versions of the Sūrya Siddhānta ; but there are 3 more verses, not given in the commentary by Raṅganātha and inserted between some preceding and following verses from the original, and these do not appear contradictory to the context.

Diffusion

Out of the authors of *Karaṇa and other works* which have adopted the numbers of revolutions and other elements from the Sūrya Siddhānta and out of the commentators thereon described above, the author of the Grahalāghava and Keśava, his father, belong to Koṅkaṇa and Mādhava, the commentator of *Bhāsvatīkaraṇa* hails from Kānyakubja, that is, Kanauj. The

*See the description of Nāramadā, later on in this very chapter.

†See Translation of the Sūrya Siddhānta by Burgess, page 278.

††Prof. Whitney died in 1894.

author of *Makaranda* belongs to Vārānasī. Paramādiśvara, the commentator of *Āryabhaṭīya*, appears to belong to Malabar province. The author of *Jyotiṣadarpaṇa* belongs to Kondāpalli which is a village somewhere in Karṇāṭaka and its latitude appears to be about 16° 43′ North. Viddaṇa, the author of *Vārṣikatantra* comes from Karnāṭaka, Vāvilāla from Tailaṅgaṇa, and Yellaya and other commentators also seem to be from Tailaṅgaṇa. The commentary of Raṅganātha and the 'Viśvanāthī' were written at Vārāṇasī. Dādābhaī belongs to South Koṅkaṇa. The Rāmavinoda was compiled at Delhi in the time of Akbar. This shows that during the period 13th to 15th century of Śaka era Sūrya Siddhānta had spread almost all over India. Although it is true that this period can not be regarded as very ancient, still the work had been universally recognized at the time of Bhāskarācārya and even before. Another thing (to be remembered) is that, as *new Karaṇa works* see the light of the day, old ones get lost because they are found useless for calculation. This shows that Karaṇa works, compiled on the basis of the modern Sūrya Siddhānta before Śaka 1220, must have been lost.

Terminology

Words like, Rāma denoting 'three', Nanda denoting 'nine' Jina and Siddha denoting twenty-four, occur a number of times in astronomical works ; but it is a surprising fact about the Sūrya Siddhānta that it claims to have been compiled at the end of the Kṛtayuga and accordingly, it nowhere uses the words denoting numbers, like *Rāma, Nanda and Jina* who lived after the Kṛtayuga. Similarly, not a single name out of those which are said to be Greek names of planets, occurs in the Sūrya Siddhānta. Only those terms which have originated from Greek, occur at places in it ; *e.g.* 'liptā' or 'liptikā' (Spaṣṭādhikāra, 45, 64,65, 66) horā (bhūgolādhyāya 19), kendra (Spaṣṭādhikāra 29, 45). There are no means to know if these words were used in the original Sūrya Siddhānta and other four Siddhāntas of the Pañcasiddhāntikā, because Varāhamihira has not given the Siddhāntas in the original form.

Bīja (Corrections)

The work entitled *Makaranda* gives the following figures of correction as from the Sūrya Siddhānta for being applied to planets :—

Planets, etc.	In a Mahāyuga: Correction to Bhagaṇas No. of Bhagaṇas	Number of Bhagaṇas as corrected
Sun	0	4320000
Moon	0	57753336
Moon's Apogee	—4	488199
Moon's Node	+4	232242
Mars	0	2296832
Mercury	—16	17937044
Jupiter	—8	364212
Venus	—12	7022364
Saturn	+12	146580

Prof. Whitney, after applying Bentley's method of comparing places of planets with respect to the Sun, has found the time when these corrections were applicable and it comes to be 1541 A.D. (*i.e.* Śaka 1463*) ; but it is clear that the correct time comes to be a date before Śaka 1400. Raṅganātha Nṛsiṃha and Viśwanātha have not mentioned this correction in their commentaries but it must have been known to them because the Makaranda work was a well known work in their time. It appears to have been omitted by them because it was not given in the original. *The Rāmavinodakaraṇa* (Śaka 1512) mentions it. The numbers denoting revolutions are similar to those above but the corrections for the moon's apogee and Mercury are positive. It may be due to the writer's error in the copy (Deccan College Collection No. 204 of 1883-84). The remaining items are exactly similar to those in the above table. The corrections given by the work *Vārṣikatantra*, which is mentioned later on in the description of that work is almost similar.

Raṅganātha remarks that some works do not give verse no. 22 that should be in the last chapter, that is the present 'mānādhyāya', but they close the chapter on elements by giving the next verse, and then they introduce a new chapter entitled 'bījopanayana' consisting of 21 verses, and close it by writing the 22nd verse from the 'mānādhyāya' followed by the remaining four verses from it. Raṅganātha has simply given the set of 21 verses, calling the chapter on 'bījopanayana' as interpolated and has not given their commentary. Even the Viśvanāthī commentary contains those verses. The 21 verses mention a correction to planets and the degrees† of epicycles of conjunction. The method of calculating the bīja correction, reveals that it is *zero* in the beginning of Kaliyuga, that it continually increases for *90000 years*, then gradually begins to decrease for the same number of years and ultimately becomes zero after *180000 years* from the beginning. The numbers of seconds of arc to be applied as correction to mean longitudes of planets are as follows :—

Sun	$+\frac{1}{750}$	Mercury'se picycle—	$-\frac{22}{750}$	Saturn	$+\frac{7}{750}$
Moon	$-\frac{3}{750}$	Jupiter	$-\frac{30}{750}$		
Mars	$+\frac{24}{750}$	Venus's conjunctions††	$-\frac{90}{750}$		

As the correction asked to be applied to the Sun in this list is positive, the length of the year would be reduced by about 5 'prativipals'. The length of the year 365d-15gh-31pal-31vipals-24prativ which is without correction, becomes 365d-15gh-31p-31vip.-19prativ. No karaṇa work is found adopting this correction.

Problems

All subject topics in our astronomical works can be reduced to *three* main problems. *The first* is the formation of the Universe and causes of the motions of celestial bodies, etc. *The second* relates to the mean motions of planets

*See Translation of the Sūryasiddhānta by Burgess, p. 20.
†The words 'Rāma' and 'Jina' occurring in this verse, have been used to denote numbers.
‡'Conjunctions' (Śighra) means the planets' conjunctions with the Sun. (R.V.V.).

in a particular period of time and their mean position at a particular moment ; and *The third* is their true motions and true positions, by which is to be understood their position which is actually observed in the heavens, as being somewhat different from their position calculated from their mean motions, and the causes of this difference, the elements for finding out this difference at a particular time and the method of finding it ; all problems (in astronomy) can thus be said to be included in these three types. That branch of astronomy which is known in English as Physical astronomy, is in the author's opinion to belong to the first type of the 'formation of the Universe.' The knowledge of astronomy concerning the second and third types, and specially the third, gradually developes with the growth of this (first) type. There is, however, no harm if it be said that no discoveries were made in our country, comparable with the several important discoveries that were made in the European astronomy after Copernicus. Hence, it can be said that the history of 'the formation of the Universe' does not hold an important position in the Hindu astronomy as it does in the European astronomy. All works have propounded almost the same views and no further discoveries have been made in them. It will, therefore, be better to describe all problems of the first type in one place. Some of them have been mentioned in the Introduction, and others will be treated later on. The problems belonging to the second type, being different for different Siddhāntas, have been described separately at their proper places ; and some topics belonging to the third type will be given later in the study of the Universe, and the remaining in the chapter on true places ; and these problems being the same in the case of each Siddhānta, it is better to mention them in one place in the chapter on true places. It will also be advantageous to indicate the differences between the Siddhāntas by comparison and this plan, when followed, will cover the study of all problems in the Siddhāntas.

The numbers of revolutions and other elements etc. in the Siddhāntas of the Pañcasiddhāntikā and in the five Siddhāntas of this chapter, have already been mentioned above. The mean positions of planets given in the Siddhāntas of the Pañcasiddhāntikā have also been compared with those calculated from European works.

A comparison of mean planets given by the modern five Siddhāntas, including the Sūrya Siddhānta, with those calculated from the European works will be made in the description of Āryabhaṭa later on.

SOMA SIDDHĀNTA

The Date

This Siddhānta has been described by Candra to the sage Śaunaka. It mentions the number of years elapsed from creation up to the beginning of the present Kaliyuga and directs us to "add the desired number of years elapsed from the present Kaliyuga". This proves that this Siddhānta has been compiled in the Kaliyuga. The real date of its compilation is the same as that established for the modern Sūrya Siddhānta or one somewhat later than it.

It has 10 chapters and 335 verses in 'anuṣṭup' metre.

A work, entitled *Jyotiṣa Darpaṇa*, mentioned above, gives a verse from the Soma Siddhānta. The Raṅganātha's commentary on the Sūrya Siddhānta gives at one place a verse from this (*viz.* Soma Siddhānta). Kamalākara, the author

of the Siddhāntatatvaviveka, has referred to the Soma Siddhānta in the following verse :—

ब्रह्मा प्राह च नारदाय हिमगुर्यच्छौनकायामलं ।।
मांडव्याय वसिष्ठसंज्ञकमुनिः सूर्यो मयायाह यत् ।। ६५ ।।

भगणमानाध्याय.

"(65) That pure (science of astronomy) which was revealed to Maya by the god Sun, was described to Nārada by Brahmā, to Śaunaka by Himaguru (Moon or Soma) and to Māṇḍavya by the sage Vasiṣṭha."

—Chapter on elements of revolutions.

The Chapter on mean places in this Siddhānta gives the following two couplets as "verses quoted from Gārga".

अथ माहेश्वरायुष्ये...ब्रह्मणोधुना ।। सप्तमस्य मनोर्याता द्वापरांते गजाश्विनः ।। २८ ।।
खचतुष्केभनागार्थशररंध्रनिशाकराः १९५५८८०००० ।। सृष्टेरतीताः सूर्याब्दा
वर्तमानात्कलेरथ ।।

"1955880000 solar years have elapsed from the creation up to the (beginning of the) present Kaliyuga, which begins from the end of the Dwāpara yuga and which is 28th (yuga) in the 7th-Manu period, belonging to the present Brahmā's day—during the life of God Śiva".

These very verses occur in Romaśa Siddhānta also, as "quoted from Garga". The former half of the first verse in this runs thus,

"परार्धप्रथमाह्निस्मिन्नायुषो ब्रह्मणोधुना"

—meaning-"in the latter half of the present day of Brahmā's life."

The word Nanda occurs at one place in this Siddhānta. It has already been pointed out above that this Siddhānta resembles the Sūrya Siddhānta in all respects.

VASIṢṬHA SIDDHĀNTA

Subject Matter

It has already been pointed out above that there are two versions of Vasiṣtha Siddhānta which are similar in principles but different only in form. Of these, the one, printed at Vārānasī, has five chapters, containing 94 verses in 'anuṣṭup' metre. It has been mentioned in the beginning and at the end that this Siddhānta was revealed by the sage Vasiṣṭha to the sage Māṇḍavya. This Siddhānta is very brief. Other Siddhāntas mention the numbers of revolutions and other elements in addition to the measures of orbital lengths also. This (siddhānta) gives only the orbital lengths and the numbers of the revolutions of planets in a Yuga have got to be calculated from them. These can be found and they agree with the Sūrya Siddhānta. This is also incomplete with respect to some other subjects. This does not mention* the number of 'sāvana' days in a yuga. It is not mentioned from what epoch the ahargaṇa

*The copy in the Deccan College Library Collection gives the number of revolutions of stars, from which the number of 'sāvana' days can be found ; but it has been pointed out (page 29) that they prove to be different (from those in the Sūrya Siddhānta).

is to be reckoned. While the use of utkramajyā (versine) has been mentioned, no lists of versines are given*. The aphelia and nodes have not at all been mentioned. The following lines are given about them :—

मंदोच्चपातभगणानुपपत्यानयेद्युगे ॥ यत्र मंदफलं शून्यं मंदोच्चस्थानमुच्यते ॥ ३१ ॥

याम्यकेंद्रफलं शून्यं पातस्तत्रविनिर्दिशेत् ॥

मध्यमाधिकार.

"Calculate from theory the numbers of aphelia and nodes in a Yuga. The point at which the 'equation of centre' is zero, is called the 'mandocca, (aphelion); the point at which the yāmya-kendra-phala (value of celestial latitude) is zero, is called a pāta (node)."

The calculator has been asked to find out the aphelia and nodes by observation, and in a way, he has been asked to compile a new Siddhānta. It describes the method of finding a'Karṇa', but it is incomplete. It has five 'adhikāras' (chapters) which deal with only the following subjects :—(i) mean places (ii) true places (iii) Shadow (three problems) (iv) miscellaneous and (v) geography. The miscellaneous chapter gives just a glimpse into the eclipses. Even the chapter on 'shadow' is very brief. A verse in the chapter on true places is given from the modern Sūrya Siddhānta. Regarding the ahargaṇa, it has been remarked that it is true for the midnight at Laṅkā ; this also proves its similarity with the Sūrya Siddhānta. The words Rāma, Nanda, and Siddha have been available in it.

DIFFERENT VERSIONS

Raṅganātha has taken a half-couplet from this as belonging to *Laghu-vasiṣṭha* Siddhānta. He has similarly given a verse regarding eclipses as "quoted by *Vṛddha Vasiṣṭha*" and at one place in his commentary on the chapter on true places he has mentioned the name of Vṛddha Vasiṣṭha. This leads me to suspect if there existed in Raṅganātha's time a different Vṛddha Vasiṣṭha Siddhānta. The verse about the eclipse quoted by him is given in 'upajāti' metre and not in 'anuṣṭupa metre. The Vasiṣṭha Siddhānta referred to by Kamaḷākara (page 29) appears to be the Laghu Vasiṣṭha Siddhānta.

The other version of Vasiṣṭha Siddhānta mentioned above as belonging to the Deccan College Collection, has only one chapter entitled 'madhya-mādhikāra', which contains only the description of the formation of the Universe and orbital lengths of planets, and does not give other chapters generally found in other Siddhāntas. All verses are in anuṣṭup metre. The remark at the end runs "in Viśvaprakāśa, from the Gaṇita branch, compiled by Vṛddha Vasiṣṭha" followed by the words "the 4th chapter on orbits". There is no hint or clue for finding where the remaining three chapters ended. This shows that the work remained incomplete. The references at the beginning show that this Siddhānta was revealed by Vasiṣṭha to Vāmadeva, and Māṇḍavya has not been mentioned.

ROMAŚA SIDDHĀNTA

This Siddhānta has been described by Viṣṇu to Vasiṣṭha and Romaśa. The verses concerning this have already been given before (page 34).

*These can be calculated from the kramajyās which are given in it.

It has 11 Chapters, consisting of 374 verses in anuṣṭup metre. It has already been mentioned that it completely resembles the Sūrya Siddhānta as regards the numbers of revolutions and other elements etc.

Any reference to verses from this Siddhānta in any other work could not be detected.

The words Nanda, and Siddha have occurred in this. The word Āra meaning Mars, has occurred once. The names of rivers have been given which included 'Kṛṣṇā veṇī.' This suggests that the author of this work might be some person from South India.

BRAHMASIDDHĀNTA CITED BY ŚĀKALYA

Author

This has 6 chapters and 764 verses. This was described by God Brahmā to Nārada. The original verses nowhere mention Śākalya's name, but each chapter ends with the phrase "in the second problem (praśna) of the Brahmasaṃhitā in Śākalya Siddhānta". Among the— 'problems' of Śākalyasaṃhitā there is not a single one which we meet at present. A number of lines have been taken in Raṅganātha's commentary on different occasions, and while giving them, the phrase "from Śākalya" is added at some places, and the phrase in Brahmasiddhānta at others. The verse in which the author of the Siddhāntatatvaviveka has referred to this Siddhānta is already mentioned (page...47...). Kamalākara has taken even some verses from this Siddhānta.

The numbers of revolutions and other elements in this tally entirely with those of the Sūrya Siddhānta in all respects and have already been given.

Subject Matter

It has not, like other Siddhāntas, separate chapters, such as a chapter on mean places, a chapter on true places, etc. Each chapter contains a subject pertaining to some 'adhikāras' and the six chapters together cover almost all the subjects usually given in a Siddhānta ; not only this, but the subject of religion also, which is never met with in an astronomical work, has been included in it. The third chapter deals with the study of Mahāpāta (parallel of declination) of the sun and the moon ; and after mentioning the 'fruits' of bath and charity undertaken on these auspicious occasions, the subject of religion has been introduced as an offshoot of the main subject and it covers the portion between the 34th verse and the end of the chapter. Thus, as many as 138 verses have been devoted to this subject which includes the following items :—the holy time for Saṃkrānti ; the end of a tithi-gaṇḍa ; the consideration as to when to accept a tithi covering the 'pradoṣa' time, and when that 'enveloping' the noon time or that which comes in contact with the former tithi etc.; similarly, the decision of the proper time for Ekādaśi, Śrāddha, Yāga (*i.e.* sacrifice) and of special rites like the Upākarma and of special tithis, like the Ganeśa Caturthī.

Date

The first chapter deals with the question who created the science of astronomy and contains the following verse,

एतच्च मत्तः शीतांशोः पुलस्त्याच्च विवस्वतः ।। रौमकाच्च वसिष्ठाच्च गर्गादपि बृहस्पतेः ।। ६
अष्टधा निर्गतं शास्त्रं ... ...

1 DGO/69

"This (science) has been created (compiled) in eight ways, viz. by me, by Soma, Pulastya, Vivasvān (sūrya), Romaka, Vasiṣṭha, Garga and Bṛhaspati".

The word *mattah* in this refers to this Siddhānta. Garga and Bṛhaspati have got only Saṃhitās to their credit, while Siddhāntas bearing the names of Soma, Pulastya, Sūrya, Romaka and Vasiṣṭha are well known. The Pulastya's Siddhānta is the same as Pauliśa Siddhānta. It is referred to even by the name 'Pauliśa' in this Siddhānta at two or three places. The following line occurs once in the first chapter:—

तस्मात् पंचसु सिद्धांतेषूक्तमार्गोविधार्यतां ॥ ६० ॥

"Hence the desired method should be followed as given by one of the five Siddhāntas."

The names, Sūrya, Soma, Romaśa and Puliśa, have also occurred at two or three other places. This clearly shows that this (Brahma) Siddhānta was compliled after all the above Siddhāntas. It is very difficult to say in what particular period of time it was compiled ; but the first chapter in this contains the line,

प्रमाथिप्रथमं वर्षं सौरं कल्पस्य सर्वदा ॥ ३७ ॥

"The name of first year of Kalpa is Pramāthi by solar measure."

Most of the works follow the method of reckoning the Prabhāva and other years of the 60-year cycle on the basis of Jupiter's motion. It is only this Siddhānta, the Romaśa Siddhānta and the commentary by Bhaṭotpala which refer to the adoption of the system, (of naming the year) by solar measure ; and it is only in this Siddhānta, that according to solar measure, the name of the first year of Kalpa is Pramāthi, and it will be found that the desired 'samvatsara' is always obtained on this basis by adding 12 to the Śaka year (in question). At present, the samvatsara is not named by Bārhaspatya system, south of Narmadā, but by solar measure and thus we get the desired samvatsara by adding 12 to the Śaka. But one year is suppressed in about 85 years if the Jovian measure is followed. Hence, we do not get the correct Jovian year by adding the same number to the Śaka year every time. The figure to be added was shorter than 12 before Śaka 743. The correct Jovian year used to be obtained by adding 12 between the period Śaka 743 and 827. This figure is to be increased by one, after every 85 years. Copper plates and other inscriptions show that the system of finding a Bārhaspatya (Jupiter's) samvatsara was the same in South India as in the North India till Śaka 743 ; but the number 12 was required to be added between Śaka 743 and 827. The author is of opinion that the system of reckoning a year by solar measure must have been adopted in South India from that period. A detailed consideration of this point will be made later on in the study of *samvatsara.* Because, this Siddhānta contains the method of finding a samvatsara by adding 12 to the current Śaka, and states the first year of Kalpa to be Pramāthi, there is no doubt that this Siddhānta must have been compiled some time after Śaka 743 and not before.

It is the speciality of this work that it gives the latitudes and longitudes of the stars in Saptarṣi group (*i.e.* Great Bear), which are not given by any other siddhānta.

FIRST ĀRYABHAṬA

Name

He has compiled the well known work *Āryabhaṭīya.* There is no other more ancient work from amongst the available 'pauruṣa' (human) astronomical works. He calls his work as Āryabhaṭīya, but many other astronomers have named it as Āryasiddhānta and it is quite proper to name it thus. A second Āryabhaṭa flourished after him and he has also written an Āryasiddhānta. It is, therefore, convenient to mention this Āryabhaṭa as Āryabhaṭa I, and his work as the First Āryasiddhānta, and the author has followed this principle all throughout.*

This Siddhānta is divided into two main parts. The first part consists of 10 verses in the 'gīti' metre ; and almost all the topics mentioned in the Madhyamādhikāra of other Siddhāntas ; for instance, the elements of revolutions etc. in a particular period of time, have been mentioned in these 10 'gītis'. This part is called the 'daśagītika'.

The second part has three chapters, which contain the remaining questions mentioned in the other Siddhāntas. It contains 108 āryās and hence, it is called the 'āryāṣṭāśata'. Some people regard the two parts as separate works. *Sūryayajvana,* one of the commentators of this work, calls the two parts as two 'prabandhas' (compositions). Each of the two parts begins with a verse which is an auspicious prayer and hence, they might have been regarded by some as two separate works. But they are interdependent and one will be of no use without the other. It is, therefore, proper to regard the two together as one work. Āryabhaṭa himself appears to hold the same view. He has not given any separate name for the first part, nor has he closed it by a conclusion. He has no doubt added a 'conclusion' at the end of the whole work together and has mentioned *Āryabhaṭīya* as the name only at that place. Similarly, the whole work together has four chapters; the author himself does not call them as 'pādas', still it has been customary with others to call them so. If the 'Daśagītika' be supposed to be a separate work, it will be said to have one 'pāda' and the other work three and these cannot justly be called 'pādas' (fourth parts). Considering, therefore, from all points of view, it will be proper to regard the 'Daśagītika and Āryāṣṭāśata' together as one Siddhānta. The Daśagītika contains two more 'gītis' in addition to the Ten ; one of them is the auspicious prayer and the second describes his numerical code. The whole work, therefore, contains 120 verses. The word 'Āryāṣṭāśata' is misleading, and it seems that because of this, some European scholars thought that it contained 800 verses. This Āryasiddhānta, along with the *Bhaṭadīpikā* commentary by Paramādīśvara has been recently printed by Dr. Kern at Leden in Holland in 1874. It was not much known to European scholars before this.

Three Schools

The astronomical works in our country are at present believed to belong to one of the three main pakṣas or schools ; the Saurapakṣa, the Āryapakṣa and the Brahmapakṣa. The basic work for the first school is the Sūrya Siddhānta, that for the second is the Ārya Siddhānta, and that for the third is the Brahma Siddhānta. The reason for the formation of the three different schools is that the length of the year according to each school is somewhat

*If any reference without the epithet 'first or second' occurs anywhere later on, it should be taken to refer to this, (that is) the first Āryabhaṭa.

different and the motions of planets in a particular period of time, say, a Kalpa or a Mahāyuga, are different. The remaining subjects in the case of all schools of all works following each of these schools are practically the same. It will be shown at the proper place when the party spirit relating to different schools raised its head.

The words Āryasiddhānta and Āryapakṣa are well known in our country but the Āryasiddhānta itself is not much known to anyone. It is considered that no orthodox astronomer in Mahāraṣṭra possesses its copy. The Āryapakṣa (school) is still flourishing and it has a number of followers ; but very few of them understand its correct form from the original Āryasiddhānta.

Numerical Code

Other astronomical works are found to be using 'bhū' for 1, 'rāma' for 3, and such other words to represent digits and numbers. But the First Āryabhaṭa, instead of following this system has adopted letters to denote numbers, as shown below :—

a—1	ḷ—100000000
i—100	e—10000000000
u—10000	o—1000000000000
ṛ—1000000	au—100000000000000

Ka— 1	Ca— 6	ṭa—11	ta—16	pa—21	ya—30	ṣa —80
kha— 2	cha— 7	ṭha—12	tha—17	pha—22	ra—40	sa —90
ga— 3	ja— 8	ḍa—13	da—18	ba—23	la—50	ha —100
gha— 4	jha— 9	ḍha—14	dha—19	bha—24	va—60	
ṅa— 5	ña—10	ṇa—15	na—20	ma—25	śa—70	

Varāhamihira has followed in the Pañcasiddhāntikā the system adopted by other Siddhāntas while using words to denote numbers; and this shows that the system was in vogue before Āryabhaṭa ; and it must have been so. Hence, Āryabhaṭa must have adopted it to represent numbers briefly and as it is not found in other works, it appears to have originated with him. This system ensures brevity. Other Siddhāntas generally require about 9 or 10 verses to mention the number of revolutions of all the planets. But it has been done only in two couplets by this system. Similarly, other Siddhāntas generally require 50 to 70 verses to be devoted to 'Madhyamādhikāra'. This system could describe almost all the subjects in 10 verses (gītis) only ; and hence, it is very easy to commit to memory the Daśagītika aphorisms written according to this system. But while this system has some advantage, it has at the same time a very serious drawback. To explain briefly the nature of the system and its inconvenience, an illustration is given below :—

The first half of the first couplet describing revolutions of planets, runs thus :—

युगरविभगणाः ख्युघृ शशि चयगियिङुशुछ्लृ कु ङिशिबुण्लृख्षृप्राक्

The number of revolutions* of 'Ku' (the earth), according to this verse comes to be 1582237500 in a Mahāyuga.

*Āryabhaṭa holds the view that the earth has the diurnal motion and that is why he has given the number of rotations of the earth. Other Siddhāntas give revolutions of stars instead.

Dr. Kern's book gives 'ṣu' in place of 'bu' in this line. 'ṣu' denotes 800000, that is, a number greater by 570000. The misprint of 'ṣu' for 'bu' has caused so much error.

ḍhi	=	500
śi	=	7000
bu	=	230000
ṇl	=	1500000000
khṣṛ	=	82000000
		1582237500

This is an error* occurring in a printed book which is very carefully checked and printed ; what then are the chances of errors having crept in in a manuscript and of these errors getting aggravated by traditional use, can be understood only by those who have occasions to go through manuscripts. Such a work is bound to go out of use in course of time, if there be no means like traditional interpretations, and checks of agreement with other works.

Motions and Revolutions of Planets

After first quoting the two couplets which mention the numbers of revolutions and other elements of planets, the author gives the numbers derived from them. The first part of the first couplet has already been given above. The remaining couplets are given below :—

शनिदुङ्ध्व गुरुखिच्युभ कुजभद्लिझनुखृ भृगुबुधसौराः ॥ १ ॥
चंद्रोच्चजृष्खिध बुधसुगुशिथन भृगुजषबिखुछृ शेषार्काः ॥
बुफिनच पातविलोमा बुधान्ह्यजार्कोदयाच्च लंकायां ॥ २ ॥

The revolutions in a *mahāyuga* as derived from these verses are :—

Rotations of the earth	1582237500	Revolutions of Jupiter	364224
Revolutions of the Sun	4320000	Revolutions of Venus	7022388
Number of sāvana days	1577917500	Revolutions of Saturn	146564
Revolutions of the Moon	57753336	Solar months	51840000
Revolutions of the Moon's Apogee	488219	Intercalary months	1593336
Revolutions of the Moon's node	232226	Lunar months	53433336
Revolutions of Mars	2296824	Tithis	1603000080
Revolutions of Mercury	17937020	Suppressed tithis	25082580

Length of the year=365d 15gh 31p 15vp.

The numbers of revolutions given by the original Sūrya Siddhānta on page 23..do not include those for Rāhu, but comparison of the remaining numbers with the above figures from the Āryasiddhānta shows that the revolutions of Jupiter and Mercury are different in the two, while the remaining numbers are the same ; and it has already been shown before, that the original Sūrya Siddhānta existed before Āryabhaṭa. This shows that Āryabhaṭa borrowed the elements of all planets except those for Mercury and Jupiter from the original Sūrya Siddhānta. The elements for the revolutions of Jupiter and Mercury appear to have been adopted by him by experience after testing their accuracy with their observed positions.

*This error cannot be detected from the commentary, but it can be easily found after considering the theory and agreement with other works. However, this error of Dr. Kern will throw several scholars into confusion.

The Yuga System

It has been remarked above that Āryabhaṭa's system is somewhat different from that of the other Siddhāntas. It is as follows. He says in his 'daśagītika' :—

काहो मनवो ढ १४ मनुयुगश्ख ७२ गतास्तेच ६ मनुयुगछ्ना २७ च ।।
कल्पादेर्युगपादा ग ३ च गुरुदिवसाच्च भारतात् पूर्वं ।। ३ ।।

"The number of Manus in a Brahmā's day is 'ḍha' (=14). A manu consists of śkha (=72) yugas. The number of manus elapsed from the beginning of Kalpa is 'ca' (=6) and that of yugas elapsed is 'chnā' (=27) ; and the number of yugapādas elapsed, prior to *Thursday*, the beginning day of Bhārata is 'ga' (=3)".

In this verse a Manu is said to consist of 72 yugas and not 71 as in others A 'sandhi'(transition or twilight period) has not been mentioned as to occurring before the commencement of each '*manvantara*'. This verse also tells us what period has elapsed from the commmencement of Kalpa up to *Thursday*, the beginning day of Bhārata*. This verse and the 2nd couplet quoted on page53, show that according to Āryabhaṭa the Kaliyuga started on Friday, and the previous day was a Thursday. But the second couplet quoted above shows that the Mahāyuga** began on Wednesday at sunrise. This shows that Āryabhaṭa does not accept the definitions of time units, *e.g.* a Dvāpara equal to twice Kali, and so on. If these definitions be accepted, the Kaliyuga would not be found to have commenced on Friday, after supposing the yuga to begin on Wednesday. We get the result if all 'pādas' or quarters of a yuga be sup posed to be equal in length .This shows that he regarded Kṛta and other 'uygapādas' as equal in length, and from this assumption it appears that the num ber of years elapsed, from the commencement of Kalpa to that of the present Kaliyuga, comes to be1986120000 and the Kalpa appears to have commenced on Thursday. The number of years elapsed from the commencement of Kalpa to that of the present Kaliyuga comes to 1972944000† according to other Siddhāntas; and according to some, who suppose that some years were spent at the beginning of the Kalpa or over Creation, it was a Sunday when the planets started to move. Brahmagupta has criticised†† Āryabhaṭa for having entertained this kind of view so different from others.

न समा युगमनुकल्पा: कल्पादिगतं कृताँदियातंच ।। स्मृत्युक्तौरार्यभटो नातो जानाति
मध्यगतिं ।। १० ।।

ब्रह्मगु सि. अ. ११.

"The measures of Yuga, Manu, and Kalpa, and the number of Kṛta and other yugas elapsed after the commencement of the Kalpa, are not equal to those mentioned by the Smṛti. This shows that Āryabhaṭa does not know mean motions of planets."

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*The word 'Bhārata' stands for 'Bhārata war'. The word is here used in the se‹ of commencement of Kaliyuga.

**Although the word mahāyuga has not been explicitly mentioned, it was evide ly so, as may be seen from context and theory.

†After including the years supposed to have been spent over creation.

††Most of the above facts have been mentioned by Brahmagupta; but instead of placing implicit faith in them, I have actually found them out for myself.

In this verse, Āryabhaṭa has been accused by Brahmagupta of not having given the Yugas, Manu and Kalpa according to the Smṛti. The length of a mahāyuga adopted by him is equal to that given by others. The number of revolutions mentioned above will show that they are divisible by four, and the second couplet says that all the planets were together in the beginning of the mahāyuga. Similarly, according to Āryabhata the 'yugapādas' (*i.e.* parts of a mahāyuga) are all equal ; and in his opinion the number of mahāyugas elapsed between the commencement of Kalpa up to the present Kṛta and other yugas is a whole number. Hence, according to his view, all planets come together at the commencement of each Kalpa, each mahāyuga and also at each Pāda or fourth part of a yuga. He has not at all given the number of revolutions of aphelia and nodes of other planets in a Kalpa. He had no reason to consider, if any years were spent over Creation ; but in his opinion, all planets come together at the beginning of Kalpa. This shows that he did not at all make the assumption that some years were spent in Creation. If he were required to give the number of nodes and aphelia of planets he would have given them on the assumption that the beginning of a Kalpa coincided with the first start of the planets for their movement.

Date

Āryabhaṭa has recorded his date in the following couplet :

षष्ठयब्दानां षष्टिर्यदा व्यतीतास्त्रयश्च युगपादा: ॥
व्यधिका विंशतिरब्दास्तदेह ममजन्मनोतीता: ॥

कालक्रियापाद

Āryabhaṭa says that he was 23 when sixty 60-year cycles (*i.e.* 3600 years) had elapsed after the three 'yugapādas,' that is, in the 3600th 'Kali-elapsed' year, which is the same as Śaka 421. This shows that his birth year was Śaka 398.

Length of a Year

The length of the year according to the Sūrya Siddhānta of the Pañcasidhāntikā is 365^{d}—15^{gh}—31^{p}—30^{vip}, and that calculated from the elements given by Āryabhaṭa above comes to be 365^{d}—15^{gh}—31^{p}—15^{vip}, that is 15 vipalas less. But according to the original Sūrya Siddhānta of the Pañcasiddhāntikā, the Kali yuga commenced at midnight on Thursday ; and Āryabhaṭa has assumed it to begin it at sunrise on Friday, that is 15 ghaṭis later ; but because the length of this year is less by 15 vipalas, the cumulative difference in 3600 years would be 15 ghaṭis less ; and hence, the moment of the mean Sun's entry into Meṣa *i.e.* the moment of the beginning of the elapsed year 3600 after Kali *i.e.* in Śaka 421, according to the original Sūrya Siddhānta and Āryasiddhānta, comes to be the same ; and this shows that he assumed the length of the year to be less by 15 vipalas in order to avoid the discrepancy which would occur, if the yuga be assumed to commence from the sunrise.

If anyone entertains any doubt about his date, the length of the year as given above will leave no room for such doubt. His date of birth is definitely Śaka 398.

Place

Āryabhaṭa observes in the first couplet of his 'Gaṇitapāda'

आर्यभटस्त्विह निगदति कुसुमपुरेऽभ्यर्चितं ज्ञानं ।।

"Āryabhaṭa, however, imparts the sacred knowledge in this (town of) Kusumapura."

From this, his place of residence seems to be Kusumapura, which is believed to be Patna in Bengal.

Subject Matter

The '*daśagītikāpāda*' of Āryabhaṭa's Siddhānta contains the numbers of revolutions and other elements of planets. The next three pādas are devoted to 'gaṇita' (Mathematics), Kālakriyā (time units) and 'Gola' (celestial sphere). The gaṇitapāda includes some subjects from arithmetic, algebra, geometry and trigonometry from among the branches of pure mathematics ; and the remaining two pādas are devoted to astronomical questions alone. As a matter of fact, according to modern conception, astronomy is a branch of applied mathematics and hence, it need not deal with arithmetic and other branches of pure mathematics; but astronomy often requires the help of pure mathematics; and hence, it is natural for such ancient works to include both types ; but such a combination is found in very few works. We have no means to know if it existed in the original Sūrya Siddhānta ; but it is not found in the Pañcasiddhāntikā and also in modern Sūrya and Soma Siddhāntas. This Āryasiddhānta, the Brahmaguptasiddānta and the second Āryasidhānta, however, do contain pure mathematics also. Bhāskarācārya's definition of a siddhānta has been given above (page xxviii of part 1), according to which he has included in the siddhāntas both the branches of mathematics, viz. 'vyakta' or known (arithmetic) and 'avyakta' or unknown (algebra), and accordingly he calls his two works *Lilāvatī and Bījagaṇita*, as parts of his work, *Siddhānta Śiromaṇi* ; still he has computed them as independent works ; and some referencesin it show that independent works on algebra were already compiled before Bhāskarācārya's time. The two Āryabhaṭas and Brahmagupta have included algebra and other branches of mathematics in the siddhānta itself ; but these subjects have been treated in separate chapters.

The contents of the 'gaṇitapāda' will be briefly described in Āryabhaṭa's work. This pāda consists of 32 couplets in addition to the benedictory verse. It contains the following subjects :—

Place names of digits of numbers, squares and cubes ; square root and cube root ; triangles, circles, and other figures and their areas ; volumes of cubes and spheres; calculation of sines and their brief treatment ; progressions, rule of three, fractions ; an interesting type or two of problems solvable by rule of three or by algebra, and a section of mathematics known as 'kuttaka' (problems of multipliers). These are the topics dealt with in the 'gaṇitapāda'. Ptolemy and the Greek astronomers before his time had no knowledge of the sines. They used to make use of chords. The Europeans, before they studied Indian astronomy, held the view that it was Al Battanī, the Arab astronomer* (who lived in the latter half of the 9th century A.D.) first made use of sines in place

*See page 56, translation of Sūryasiddhānta by Burgess.

of chords. But this work of Āryabhaṭa shows that we knew the use of sines in Śaka 421. Even the modern Sūrya-Siddhānta gives sines. One more thing worth being specially mentioned is that Āryabhaṭa has very accurately given the ratio of the circumference of the circle to its diameter by the following verse :—

चतुरधिकं शतमष्टगुणं द्वाषष्टिस्तथा सहस्राणां ।। अयुतद्वयविष्कंभस्यासन्नो
वृत्तपरिणाहः ।। १० ।।
गणितपाद.

The approximate length of the circumference of a circle whose diameter is 2000 is 62000 increased by "104 multiplied by 8". This gives 62832 as the length of the circumference corresponding to 2000 as diameter, which gives 1:3.1416 as the ratio. Even this has been given by him as only approximate.

DIURNAL MOTION OF THE EARTH

Āryabhaṭa is the only astronomer in our country who holds that the earth rotates round itself; in other words, he holds that the earth has a diurnal motion. He remarks :—

अनुलोमगतिर्नौस्थः पश्यत्यचलं विलोमगं यद्वत् ।। अचलानि भानि तद्वत् समपश्चिमगानि
लंकायां ।।
गोलपाद.

"Just as one, sitting in a boat, observes stationary objects moving backwards; similarly, to an observer in Laṅkā (i.e. equator) the stationary stars appear to be moving towards the West".

The commentator of Bhaṭaprakāśikā has attempted to make out in the following lines that even Āryabhaṭa holds the view that the earth is stationary.

"भानि कर्तृभूतानि अचलानि भूमिगतानि वस्तूनि कर्मभूतानि विलोमगानीव
प्राचीं दिशं गच्छंतीव पश्यंति"*

But Āryabhaṭa instead of giving the revolutions of stars in the list of elements has given the rotations of the earth. He has also remarked at another place (4th couplet of daśagītika) that the earth revolves through one minute of arc in a unit of time known as 'prāṇa' (i.e. $\frac{1}{6}$ of a pala). Similarly, Brahmagupta and others have criticised Āryabhaṭa for holding the view that the earth rotates. Brahmagupta says :—

प्राणेनैति कलां भूर्यदि तर्हि कुतो व्रजेत् कमध्वानं ।। आवर्तनमुर्व्याश्चेन्न पतंति
समुच्छ्रयाः कस्मात् ।।
ब्र. सि. अ. ११.

If it be assumed that the earth does rotate one minute arc in one 'Prāṇa' unit of time, where, then, does it go and by what track, and how is it that objects situated as elevated places do not fall off ?

*Meaning :—The stars, (when they take the place of a 'subject') observe the earthly objects (which became an 'object') as moving towards the east.

The compiler of Bhaṭaprakāśikā commentary has offered his comments by taking 'bha' (i.e. bhamaṇḍalam) in place of 'bhūḥ' in the couplet 'prāṇenaiti kalāṃ bhūḥ'. The Āryabhaṭa's couplet just following the Āryā "anuloma etc.", runs thus :—

उदयास्तमयनिमित्तं नित्यं प्रवहेण वायुना क्षिप्तः ।। लंकासमपश्चिमगोभपंचरः सग्रहो भ्रमति ।। १० ।।

गोलपाद.

"The starry cage, being daily tossed by the 'pravaha' wind, with the object of causing rises and sets, is seen at the equator to revolve from east to west."

Considering all things, however, it appears that it was Āryabhaṭa's definite view that the earth rotates. He only accepts the earth's diurnal rotational movement*. It does not appear that he held the view of the earth's revolution round the sun.

This Siddhānta by Āryabhaṭa does not contain chapters like other Siddhāntas ; but it deals with almost all the subjects in them excepting those in the chapters on "elevation of the moon's cusps" and "conjuctions of planets with stars". Brahmagupta has criticised him that the *Āryabhaṭīya* will not be helpful in obtaining the knowledge of elevation of the moon's cusps, shadow, etc. This Siddhānta does not give the longitudes and latitudes of Junction-Stars like other Siddhāntas, and this is another drawback. Had these been given, it would have been a great help to the history of astronomy, since the date of Āryabhaṭa is definitely known; not that this subject was unknown in his time or before, for the Pañcasiddhāntikā gives some information about the latitudes and longitudes of Junction-Stars of nakṣatras. This Siddhānta mentions nothing about the *precession of equinoxes* which is again a very important subject.

KARAṆA WORK OF ĀRYABHAṬA

This Āryasiddhānta is very brief; still, the subjects dealt with in it are so treated as to be clearly understood. Brevity has not caused any lack of clarity. Still its general form shows that it has not been compiled with the object of being useful to astronomers for every day use, but for mentioning the important subjects which are the Siddhāntas or established truths. It is true that a Siddhānta work cannot be useful for every day purposes; a Karaṇa work is necessary for the purpose. The work, however, is not extensive like other Siddhāntas and does not deal with all the subjects. It is true that the calculator requires more time if he takes the help of the modern Sūrya Siddhānta, Brahma Siddhānta or Siddhānta Śiromaṇī instead of any Karaṇa work, but he will not be handicapped if he has only one Siddhānta available and not others. Such is not the case with this Siddhānta. For instance, it does not give the methods of calculating tithis, nakṣatras and karaṇa nor does it give the calculation of 'mahāpāta'. It is not that Āryabhaṭa did not know what 'mahāpāta' is; the Āryasiddhānta does refer to it. Similarly, the terms tithi, nakṣatra and karaṇa must have been known in his time. There are also other subjects which are found in other siddhāntas. This leads me to think that

*It is stated on page 2 of Grant's History of Physical Astronomy :—It is said that it was the view of Nicetas of Syracuse that the earth only rotates about its axis. It is also said that it was the opinion of Pythagoras, the Greek philosopher (6th century B.C.) that the sun is at the centre of the Universe and the earth revolves round him. But the auther does not think that these views were formed from the results of observations, and that accurate methods of calculating planetary places were established by them. Perhaps, these might have been simply notions.

Āryabhaṭa might have compiled some Karaṇa work. Āryabhaṭa's conception of the day commencing with sunrise is given by the second couplet from Daśagītika given above (page 53); but Varāhamihira remarks that according to Āryabhaṭa, the day is said to commence even from the midnight at Laṅkā (page 25). This statement of Āryabhaṭa is not found in the Āryabhaṭīya. and even Brahmagupta is not seen to criticise him for this. It proves that even at the time of Brahmagupta, the Āryabhaṭīya did not contain some such couplets. Brahmagupta has referred to the two parts of Āryasiddhānta by these very words, viz. 'daśagītika and āryāṣṭāśata'. From this it appears that no one has added anything to or taken away from the Āryasiddhānta which existed before Brahmagupta. The Varāhamihira's statement, therefore, suggests that Āryabhaṭa must have compiled some other work, and Brahmagupta's Khaṇḍakhādyaka and Varuṇa's commentary on it, lead one to conjecture that there must have existed some Karaṇa work written by Āryabhaṭa. It is, however, not available at present.

Criticism

Brahmagupta has levelled a great deal of criticism against Āryabhaṭa After enumerating different points of criticism, he further remarks :—

स्वयमेव नाम यत्कृतमार्यभटेन स्फुटं स्वगणितस्य ।। सिद्धं तदस्फुटत्वं ग्रहणादीनां
विसंवदति ।। ४२ ।।
जानात्येकमपि यतो नार्यभटो गणितकालगोलानां ।। न मया प्रोक्तानि ततः पृथक्
पृथक् दूषणान्येषां
।। ४३ ।। आर्यभटदूषणानां संख्यां वक्तु न शक्यते ।।
ब्र. गु. सि. अ. ११.

"Aryabhaṭa himself has claimed the correctness of this calculation; but that calculation has been proved to be incorrect on account of its disagreement with the actual phenomena of eclipses, etc. Since Āryabhaṭa understands nothing of mathematics, celestial sphere or time, I have not mentioned separately his demerits concerning short-comings in respect of other subjects. It is impossible to enumerate all demerits of Āryabhaṭa."

The fact that calculations of eclipses, etc., made from Āryabhaṭa's works showed disagreement with the observed results is worth-considering. Their correctness or otherwise can be judged from some of the points of criticism enumerated above. Although it is true that some of the points are correct. still, Brahmagupta's statement betrays a great deal of prejudice.

Loss of Works

Brahmagupta says :—

कालांतरेण दोषा येन्यैः प्रोक्ता न ते मयाभिहिताः ।।

"I have not repeated the demerits which have been stated by others as time elapsed."

But, of the available works compiled before Brahmagupta, it is only the Pañcasiddhāntikā which mentions Āryabhaṭa's name only, and makes no mention of any of his faults. This shows that some works of pre-Brahmagupta period must have been lost. The works of authors belonging to the period before Śaka 421 and mentioned above are not at present available.

HIS CALIBRE

The main criterion of testing the capability of the author of an astronomical work, is the agreement of its calculation with observation, and this criterion will reveal a high degree of capability in the case of Āryabhaṭa. It has been noted above that he has found the numbers of revolutions of Jupiter and Mercury to be different from those of earlier works ; it, however, appears that he improved the earlier works as far as the calculation of true places of planets was concerned. According to Brahmagupta, Śrīṣeṇa and Viṣṇucandra borrowed the method of calculating planets' places, the aphelia, nodes and epicycles from Āryabhaṭa's works. The very fact, that although the original Sūrya Siddhānta of the Pañca-siddhāntikā, the works of Lāṭa, and others, and the Āryasiddhānta existed before them, they chose to borrow the calculation methods only from Āryabhaṭa's works, easily shows that he possessed greater capability than others as far as agreement with observation was concerned. The table of 'paridhyaṃśa' (i.e. epicycles in degrees) of all the authors, given later on, in the chapter on true places, will show that Āryabhaṭa's 'paridhyaṃśas' of the cycles of apsis and conjunctions, which form the main item in calculating true places of planets, were different from those of the Pañcasiddhāntikā. This shows that he improved the methods of calculating true places. Even though Brahmagupta, an adept in fault finding, has remarked that the demerits of Āryabhaṭa cannot be enumerated, he observes in the first couplet of Khaṇḍakhādyaka.

वक्ष्यामि खंडखाद्यकमाचार्यार्यभटतुल्यफलं ।।

"I will compile the work Khaṇḍakhādyaka which would give results equal* to those of the learned Āryabhaṭa."

Brahmagupta had to set aside the vanity about his own Siddhānta, and to say that he has compiled a work which would be a match for that of his greatest rival. This clearly reveals Āryabhaṭa's capability and it becomes further enhanced in our eyes because his work attained prominence, even when original Sūrya Siddhānta and other works compiled before his time were in existence and this fact is further confirmed from the following verse :—

सिद्धांतपंचकविधावपिदृग्विरुद्धमौढयोपरागमुखखेचरचारकलृप्तौ ।।

सूर्यः स्वयं कुषुमपुर्यभवत् कलौ तु भूगोलवित् कुलप आर्यभटाभिधानः ।।

It is not known who wrote this and when. Dr. Kern has quoted it in the Introduction. The compiler of this verse states that because the calculation of setting of planets and eclipses based on the existing methods of the five Siddhāntas did not tally with the observed results, the Sun god himself was born in Kusumapura, under the name of Āryabhaṭa in order to find out correct motions of planets. This states that the five Siddhāntas did not give results agreeing with observations. It, therefore, shows that some one has compiled the verse soon after Āryabhaṭa. This also clearly shows that Āryabhaṭa was regarded as very capable, and the capability was really very great con sidering the age in which he lived. Āryabhaṭa himself observes:—

क्षितिरवियोगाद्दिनकृद्रवींदूयोगात् प्रसाधितश्चंद्रः ।। शशिताराग्रहयोगात्तथैव ताराग्रहा सर्वे ।। ४८ ।।

सदसज्ज्ञानसमुद्रात् समुद्धृतं देवताप्रसादेन ।। सज्ज्ञानोत्तमरत्नं मया निमग्नं स्वमतिना वा ।। ४९ ।

*This comparison is not complete. To what extent it holds good will be shown later in Brahmagupta's account.

"I have finally corrected* the 'Sun' from the yoga (conjunction) of the sun with the earth, the 'moon' from the conjunction of the moon and the sun; and all the 'planets' from the conjunctions of the moon and stars with the planets. I took out the jewel, in the form of true knowledge, through God's favour or with my own intellectual power, from the ocean of real and false knowledge."

Eclipses and conjunctions can lead us to find even the mean motions; but it is the true place which is chiefly found from them. This verse and the one referred to before this, will show that Āryabhaṭa has made an improvement in the calculation of true places. Similarly, his high capability can be seen from the fact that he made researches by means of observation and intelligence after critically studying the old works with common sense.

ITS INFLUENCE AND FOLLOWERS

Utpala has extracted a number of couplets from Āryabhaṭīya in his commentary on Bṛhatsaṃhitā; and extracts from it are also found in a number of works compiled later on. LALLA, the famous astronomer, was a follower of Āryabhaṭa. He has suggested a correction to the planetary motions given by Āryabhaṭa. The Karaṇa work, named *Karaṇaprakāśa* which belonged to the Ārya-Pakṣa and was compiled in Śaka 1014, has been compiled after applying Lalla's corrections to the planetary places and motions obtained from the elements given by Āryabhaṭa. (This will be explained in detail later on). Similarly, DĀMODARA's Karaṇa work, named *Bhaṭatulya*, which was compiled in Śaka 1339, follows the same method. Many people use Karaṇaprakāśa even now for calculation and many are its followers. The *Grahalāghava* has adopted the positions of Jupiter, Mars and Rāhu from the Karaṇaprakāśa and the Grahalāghava is followed in more than one third part of India.

PLACE

It shows that the Āryasiddhānta is even now followed, if not in its original form, at least with the application of corrections to it. Quotations from Āryasiddhānta are not found in astronomical works which were compiled in Mahārāṣtra and Vārānasī after Śaka 1400. It has already been pointed out above that the Ārya siddhānta is not available on our side in its original form. Dr. Kern has published an Āryabhaṭīya on the basis of three manuscripts obtained by him. All these manuscripts are written in the Malayalam script. This shows that the Āryasiddhānta is still known in South India and specially in the Malabar province. The provinces which speak the Tamil and Malayalam dialects follow the almanac computed on solar basis, and it belongs to the Āryapakṣa, since the year adopted in it is according to the first Āryasiddhānta. The Vaiṣṇavas are adherents of the Āryapakṣa. They form a large part of the population in Karnataka and Mysore. Patna in Bengal (at that time) is believed to be Āryabhaṭa's place; but there is some doubt about it; because, the Āryasiddhānta is not at all in use in Bengal. It appears from this that the Kusumapura mentioned by Āryabhaṭa might be some place in the south; nothing can be, however, said about it for certain.

PLANETARY CORRECTIONS

It has already been pointed out that the places of planets given by the Āryasiddhānta, sometimes tally exactly with those calculated from European tables; but for a clearer understanding and consideration of them, the mean positions of planets true for the mean Sun's entry into Aries of Śaka 421 (i.e. 499 A.D.) as calculated from the *Āryabhaṭīya* and also from the European tables have been given together in a tabular form, on page 62-63

*The first sentence refers to the lunar eclipse and the second to the solar eclipse.

Mean places of planets for 15 Ghaṭikās after sunrise on sunday, Caitra Kṛṣṇa 9, śaka 421.

Planets	Original Sūrya Siddhānta	Variation+ or—from column 12	First Ārya Siddhānta	Variation+ or—from column 12	Five Modern Sūrya & other Siddhāntas	Variation+ or —from column 12
	1	2	3	4	5	6
	s ° ′ ″	° ′ ″	s ° ′ ″	° ′ ″	s ° ′ ″	° ′ ″
Sun	0	0	0	0	11 29 58 37	—0 1 23
Moon	9 10 48 0	—0 4 48	9 10 48 0	—0 4 48	9 10 29 33	—0 23 15
Moon's Apogee	1 5 42 0	—0 28 30	1 5 42 0	—0 28 30	1 0 53 51	—4 16 39
Rāhu			11 22 12 0	—0 42 18	11 18 36 4	—4 18 14
Mars	0 7 12 0	+0 7 0	0 7 12 0	+0 7 0	0 9 23 16	+2 18 16
Mercury	6 0 0 0	—3 22 12	6 6 0 0	—2 37 48	6 17 54 16	+14 32 4
Jupiter	6 6 0 0	—1 29 54	6 7 12 0	—0 17 54	6 5 59 53	—1 30 1
Venus	11 26 24 0	+0 6 24	11 26 24 0	+0 6 24	11 22 45 45	—3 31 51
Saturn	1 19 12 0	+0 51 54	1 19 12 0	+0 51 54	1 20 23 57	+2 3 51

Planets	Variation in Solar distance as compared with Col. 12	Brahmagupta Siddhānta	Variation + or — from Col. 12	Variation in Solar distance as compared with Col. 12	Sāyana places calculated from Keropant's planetary tables	Nirayana places obtained from Col. 11 by applying ayanāmśa correction of +16′ 54″
	7	8	9	10	11	12
	° ′ ″	s ° ′ ″	° ′ ″	° ′ ″	s ° ′ ″	s ° ′ ″
Sun	0	0 0 51 45	+0 51 45	0	11 29 43 6	0 0 0 0
Moon	—0 21 52	9 11 31 46	+0 38 58	—0 12 47	9 10 35 54	9 10 52 48
Moon's Apogee	—4 15 16	1 7 21 3	+1 10 33	+0 18 48	1 5 53 36	1 6 10 30
Rāhu	—4 16 51	11 23 23 14	+0 28 56	—0 22 49	11 22 37 24	11 22 54 18
Mars	+2 19 39	0 8 4 45	+0 59 45	+0 8 0	0 6 48 6	0 7 5 0
Mercury	+14 33 27	6 0 41 2	—2 41 10	—3 32 51	6 3 5 18	6 3 22 12
Jupiter	—1 28 38	6 7 28 9	—0 1 45	—0 53 30	6 7 13 0	6 7 29 54
Venus	—3 30 28	11 26 57 12	+0 39 36	—0 12 9	11 26 0 42	11 26 17 36
Saturn	+2 5 14	1 19 0 1	+0 39 55	—0 11 50	1 18 3 12	1 18 20 6

For a simultaneous comparison of all the works, the places of planets have been calculated from the original Sūrya Siddhānta, the modern Sūrya Siddhānta, and the Brahma Siddhānta for the same moment and have been noted in the same table.

The moment of mean Sun's entry into Aries for the (elapsed year) Śaka 421 works

	gh.	pal.	
Original Sūrya Siddhānta . . .	15	0	Time elapsed after mean sunrise at Ujjayinī on Sunday, 9th lunar day of the dark half of 'amānta' Caitra, i.e. the 21st of March.
First Ārya Siddhānta	15	0	
The modern five Siddhāntas (Sūrya . and others)	16	24	
Brahma Siddhānta (Caitra Kṛṣṇa 8, Saturday).	22	30	

The 11th column on page 63 above, gives places of planets as calculated from Keropant's planetary tables ; they are, therefore, as accurate as those calculated from European tables. They are Sāyana. Out of these, the secular equation is applied to the moon, the moon's apogee and the moon's node only. After applying the ayanāṃśa correction of 'plus 16′-54″' in Śaka 421 to the planets in this column, the nirayaṇa positions so found have been given in the 12th column, and the places given by works, like the original Sūrya Siddhānta and others, have been compared with these figures. The precessional motion in 20 years comes to be 16′-54″ ; and taking this figure as the ayanāṃśa for Śaka 421, therefore, is equivalent to taking zero as the ayanāṃśa for Śaka 441. This year is very near to Śaka 444. It is true that the equinox was near the junction-star of Revatī about Śaka 496, and it is suggested that the aynāṃśa for that year should be taken as zero. But it has been pointed out thereafter in the study of the precession of equinoxes that the Indians were right in supposing Śaka 445 as the zero-precession year according to their system. The object of assuming 16′-54″ as the ayanāṃśa, while comparing the figures, is that it would facilitate the comparison with resect to the sun. It is not that there will be much error resulting from this. The error, at the most, would be four minutes of arc.

There is no harm if seconds of arc be neglected while making a comparisons since, they can be said to be carrying no value in the comparison. The sun' longitude as given in columns 1 and 3 is zero ; and hence, the results of comparison of the planets' places in them with those of the 12th column which are noted in columns 2 and 4 are with respect to the planets and to the sun also, which means that the figures in columns 2 and 4 give the differences obtained by comparing the planets' positions independently with those given in column 12. Similarly, the figures in columns 2 and 4 indicate also the differences obtained by comparing the figures, showing positions of planets in column 12 ahead of the sun's position given in it and the figures indicating the advance of planetary positions in columns 1 and 3 over the positions of the sun given in them. The sun's longitude given in cols. 5 and 8, is not zero ; and hence, the differences in the planets' places in these columns, as independently compared with those in the 12th column, have been shown in the 6th and 9th columns; and their differences, when compared with respect to the sun, have been given in the 7th and 10th columns.

The difference in the case of only Jupiter and Mercury out of other planets

given by the original Sūrya-Siddhānta, is greater than one degree, while that of others is less than that. Only Mercury, as given by First Āryasiddhānta differs by more than 2 degrees, while other planets do not differ by more than 51 minutes. Almost all the planets, except the moon, obtained from the modern Sūrya-Siddhānta differ by a considerable quantity. As for the differences in the positions of planets (with respect to the sun) in the case of Brahmagupta Siddhānta and shown in column 10, that of Mercury only is really considerable, that of Jupiter is 53 minutes while that of others is less than 22 minutes of arc.

The whole discussion shows that there is no harm if it be said that the places of planets of all Siddhāntas, except those of modern Sūrya Siddhānta, for Śaka 421, used to prove fairly correct. The position of the moon is no doubt given very accurately by all. All except Brahmagupta, have given the same number of revolutions for the moon; but the moon's place, as calculated from the modern Sūrya Siddhānta has come to be somewhat different from that of others because of different lengths adopted for a year. The discrepancy in the case of Mercury, according to all Siddhāntas, is considerable. The reason for this appears to be that its constant proximity to the sun allows rare chances for its observation.

The method of judging the accuracy or otherwise of astronomical works by comparing the mean places of planets as found from the European and Indian works has been shown to be not without risk in all cases and all circumstances, as explained in the course of the discussion of Bentley's method of determining the date of old works (page 30). But in the absence of any better way of judging how far our works agreed with observations in respect of the results of their calculations, the writer has followed the same method.

The numbers of revolutions and other elements mentioned by our different works have been given before and some more will be given later on. But, the periods of one sidereal revolution as found from European works and our works, have been given further (page 66) in order to facilitate the comparison of the two.

Ptolemy's measures given in it have been taken from the translation of the Sūrya Siddhānta by Burgess, and those for the Sūrya Siddhānta and Brahma Siddhānta (or Siddhānta Śiromaṇi) have also been adopted from the same book. There is, however, probably no error* in them. The figures derived from the *Practical Astronomy* by *Loomis* have been adopted as the modern European measures.

The length of the year, as adopted by our Sūrya Siddhānta, when compared with that of the modern European works, appears to be greater by about 8 palas—34.5 vipalas and that of the Brahma Siddhānta by about 7 palas—25.6 vipalas. Even though the motion of the moon is considerable, there is almost no error in it. The time taken by the moon's node for one revolution is longer by 4 days and that in the case of Saturn is different by 6 days; the discrepancies in the case of others are less than a day.

PTOLEMY

Prof. Whitney observes that he has calculated Ptolemy's elements from the daily motions given by him, after taking into account the precessional motion (of 36″ per year) as adopted by him. They do not at all resemble the elements given by our Siddhāntas. *This proves that our Siddhānta works have not borrowed the places and motions of planets from Ptolemy's works.*

*Even if there be one, no calculation of the author given in this book has been made on the basis of these elements.

Times required for one sidereal revolution

Planets	Modern Sūrya Siddhānta				Brahmagupta Siddhānta				Ptolemy's work				Modern European works			
	Days	gh.	p.	v.	Days	gh.	p.	v.	Days	gh.	p.	v.	Days	gh.	p.	v.
Sun	365	15	31	31.4	365	15	30	22.5	365	15	24	31.5	365	15	22	56.87
Moon	27	19	18	1.6	27	19	18	0.25	27	19	18	0.2	27	19	17	58.866
Moon's apogee	3232	5	37	13.6	3232	44	2	45	3232	24	40	34	3232	34	31	14.088
Meon's node	6794	23	59	23.5	6792.	15	14	14.7	6799	58	16	38.5	6798	16	44	24.000
Mercury	87	58	10	55.7	87	58	11	43.7	87	58	11	47.2	87	58	9	24.998
Venus	224	41	54	50.6	224	41	52	34.7	224	42	9	52	224	42	2	47.486
Māra	686	59	50	5.87	686	52	52	33.7	686	58	49	50.2	686	58	46	2.518
Jupiter	4332	19	14	20.9	4332	14	24	19.2	4332	45	22	56.2	4332	35	5	17.49
Saturn	10765	46	23	4.1	10765	48	54	51.2	10758	44	30	37.2	10759	13	10	57.49

Aphelia and Nodes at the commencement of the Kaliyuga

Planets	Modern five (Sūrya & other) Siddhāntas				Brahmagupta Siddhānta				Second Ārya Siddhānta				Parāśara Siddhānta				Sāyana position calculated from Keropant's tables			
Aphelia	s	°	′	″	s	°	′	″	s	°	′	″	s	°	′	″	s	°	′	″
Sun	2	17	7	48	2	17	45	36	2	17	45	36	2	17	45	36	0	15	12	6
Mars	4	9	57	36	4	8	18	14	4	3	50	24	4	2	43	36	2	1	11	0
Mercury	7	10	19	12	7	14	47	2	7	0	14	24	7	0	40	19	5	27	46	18
Jupiter	5	21	0	0	5	22	15	36	5	22	48	0	5	22	35	2	3	23	54	42
Venus	2	19	39	0	2	21	2	10	2	20	38	24	2	20	42	43	8	2	26	30
Saturn	7	26	36	36	8	20	53	31	7	23	9	36	7	28	14	53	5	29	7	36
Nodes																				
Mars	1	10	8	24	0	21	59	46	1	10	19	12	1	9	3	36	0	10	49	0
Mercury	0	20	52	48	0	21	20	53	0	20	9	36	0	21	1	26	11	17	0	0
Jupiter	2	19	44	24	2	22	2	38	2	20	38	24	2	21	43	12	1	19	48	6
Venus	2	0	1	48	2	0	5	2	2	0	28	48	2	0	5	2	1	2	39	54
Saturn	3	10	37	12	3	13	23	31	3	10	48	0	3	10	26	24	2	0	9	0

Aphelia and Nodes in Śaka 421 (i.e. Kali elapsed year 3600)

Planets	From Keropant's planetary tables	First Ārya Siddhānta: Place	First Ārya Siddhānta: Variation from Keropant	Modern Sūrya Siddhānta: Place	Modern Sūrya Siddhānta: Variation from Keropant	Brahmagupta Siddhānta: Place	Brahmagupta Siddhānta: Variation from Keropant
1	2	3	4	5	6	7	8
	s ° ′	s °	° ′	s ° ′	° ′	s ° ′	° ′
Apsides							
Sun	2 17 7	2 18	+ 0 53	2 17 15	+ 0 8	2 17 54	+ 0 47
Mars	4 8 11	3 28	—10 11	4 10 1	+ 1 50	4 8 23	+ 0 12
Mercury	7 24 1	7 0	—24 0	7 10 26	— 13 35	7 14 53	— 9 8
Jupiter	5 20 38	6 0	+ 9 22	5 21 16	+ 0 38	5 22 31	+ 1 53
Venus	9 21 3	3 0	—201 3	2 19 49	—211 14	2 21 14	—209 59
Saturn	8 5 12	7 26	— 9 12	7 26 37	— 8 35	8 20 54	+ 15 42
Nodes							
Mars	1 8 9	1 10	+ 1 51	1 10 5	+ 1 56	0 21 55	— 16 14
Mercury	1 0 18	0 20	— 10 18	0 20 44	— 9 34	0 21 12	— 9 6
Jupiter	2 25 30	2 20	— 5 30	2 19 41	— 5 49	2 22 2	— 3 28
Venus	2 3 40	2 0	— 3 40	1 29 46	— 3 54	1 29 49	— 3 51
Saturn	3 10 13	3 10	— 0 13	3 10 25	+ 0 12	3 13 13	+ 3 0

APHELIA & NODES

The positions of aphelia and nodes of all planets according to different authors at the commencement of the Kaliyuga and those for the year Śaka 421 (i.e. Kali elapsed year 3600) have been given respectively in tables on pages 67 and 68. Prof. Whitney, after giving the aphelia and nodes according to Ptolemy and the Sūrya Siddhānta together, has suggested that the Hindus must have taken them either from Ptolemy or from other earlier Greek works. But the following comparative table shows that this statement is incorrect, as can be seen from the positions of aphelia and nodes according to Ptolemy and also the figures for the same for Ptolemy's time i.e. the year 148 A. D. (Śaka year 70) as calculated from *Keropant's* planetary tables which give modern European figures.

A comparison of Ptolemy's figures for the Apsides and Nodes (in Śaka 70) with those calculated from Keropant's tables :—

Planet	Apsides			Nodes		
		Ptolemy's work			Ptolemy's work	
	(Sāyana) from Keropant's tables	Position	Diff. with Keropant's place	(Sāyana) from Keropant's tables	Position	Diff. with Keropant's place
1	2	3	4	2	3	4
	s ° ′	s ° ′	° ′	s ° ′	s ° ′	° ′
Sun . .	2 11 5	2 5 30	— 5 35			
Mars . .	4 1 39	3 25 30	— 6 9	1 5 29	0 25 30	— 9 59
Mercury .	7 18 32	6 10 0	— 38 32	0 26 5	0 10 0	—16 5
Jupiter . .	5 15 7	5 11 0	— 4 7	2 22 1	1 21 0	—31 1
Venus . .	9 16 18	1 25 0	—231 18	2 0 39	1 25 0	— 5 39
Saturn . .	7 28 45	7 23 0	— 5 45	3 7 28	6 30 0	+85 32

The positions for apsides and nodes according to our old works (as shown on pages 67 and 68) at the commencement of Kaliyuga and in the Kali elapsed year 3600 will show that the variation during 3600 years is very small; and the reason for this is their very slow motion. None of our Siddhāntas mention the motion of the apsides and nodes as greater than 1 degree in 13000 years. The figures calculated from Keropant's tables and shown in the two tables above show that, if the equinox be taken to be the initial point, in other words, if the sāyana system be followed, the motion appears to be considerable ; but the motions appear to be negligibly small if sidereal i.e. the nirayaṇa basis be adopted.

The table on page 70 , gives the annual motions of apsides and nodes very accurately calculated by modern European methods following the sāyana system and also the actual yearly motion* according to the nirayaṇa system.

*These have been taken from Practical Astronomy by Loomis.

Yearly motions of Apsides and Nodes.

Planets	According to European Calculations		That which must be adopted according to our Nirayaṇa system	According to the Sūrya-Siddhānta
	Sāyana	True Nirayaṇa		
1	2	3	4	5
Aphelia	Seconds	Seconds	Seconds	Seconds
Sun	+61.5	+11.24	+ 1.5	+0.1161
Mars	+65.7	+15.46	+ 5.7	+ .0612
Mercury	+56.1	+ 5.81	— 3.9	+ .1104
Jupiter	+56.9	+ 6.65	— 3.1	+ .27
Venus	+47.0	— 3.24	—13.0	+ .1605
Saturn	+69.6	+19.31	+ 9.6	+ .0117
Nodes				
Mars	+25.0	—25.22	—35.0	—0.0642
Mercury	+40.2	—10.07	—19.8	— .1464
Jupiter	+34.3	—15.90	—25.7	—.0522
Venus	+29.7	—20.50	—30.3	— .2709
Saturn	+30.7	—19.54	—29.3	— .1986

This motion has been calculated after assuming 50.2″ as the equinoctial motion ; but our works have assumed 60″ as the equinoctial motion. Hence. the motion shown in column 4 is the actual annual motion according to our works ; and if the figures denoting motions according to European works are to be compared at all, they should be compared with this motion. Even when the comparison is so made, the motions according to the Sūrya Sidhānta are found to be very erroneous. The motions according to other Siddhāntas can also be said to be equally erroneous. None of the other works gives for the annual motions of an aphelion or node, a figure greater than one third of a second. It is greater than 1 second according to the European system. It is very easy to criticise our works regarding this discrepancy, simply by seeing the figures on papers. But he who knows how difficult it is to observe an arc of one second in the sky even with the help of very accurate modern instruments will not blame them in that way. It has been observed by the author with naked eyes some conjuctions of planets with stars, and it has been our experience that those two planets etc. which are actually apart from each other by 5 minutes (300 seconds) of arc or more, as observed through a telescope appear to be in close contact with each other as seen with naked eyes, in other

words, there appears to be no distance between them. Hence, this fact should be borne in mind while comparing the figures of our works with accurate measures of European works and we must praise our works instead of condemning them regarding the apsides and nodes. We should appreciate the authors of our works, in as much as they recognized the fact that the motions of apsides and nodes are very small. It should only be seen as to how much accurate the longitudes of the apsides and nodes calculated from their works, prove to be. The postions of the apsides and nodes in Śaka 421, have been given above (page 68) and their differences obtained after comparison with the figures calculated from Keropant's tables, have also been given. It shows that the positions given by our Siddhāntas are very near to actual positions. Keropant-calculation gives sāyana results, but since the ayanāṃśa in Śaka 421 was about 20 minutes only, there is no harm in comparing the figures taking them as nirayaṇa. The Sun's apogee, in fact, shows only a very little error ; but the aphelion of Venus, however, shows a considerable error. Its cause is not known ; it is a problem worth considering. But looking to the remaining aphelia, it appears that the aphelion of Mercury, according to First Āryabhaṭa, is less by 24 degrees, while others differ within 10 degrees. Those of Sūrya Siddhānta are more accurate than these, that of Mercury being less by 13 degrees and that of Saturn less by 8 degrees. The aphelia of Mars and Jupiter show only a small difference. Those mentioned by Brahamagupta are as accurate as in the Sūrya Siddhānta or even more so. The table given on page 69 compares Ptolemy's aphelia with those derived by Keropant's calculation. These positions given by Ptolemy were presumably sāyana like his other positions and the fact is corroborated from the positions of the sun's apogee and hence, there is no harm, if the figures are compared with Keropant's sāyana calculations ; and the comparison reveals that even his position of the aphelion of Venus is considerably wrong and his aphelia on the whole show greater errors than those in the Sūrya Siddhānta and Brahma Siddhānta.

The nodes given on page 68 show an average error of 4° in Āryabaṭa's places. Those of the Sūrya Siddhānta are in error by 4°, those of Brahma gupta by 7° and those mentioned by Ptolemy (page 69) are erroneous by as many as 30 degrees. The nodes of Jupiter and Saturn given by him are considerably wrong. The position of the sun's apogee as given by him is 65° 30′. The sāyana position of the sun's apogee in his time i.e. about 150 A.D. comes to be 71°. By no other method can one possibly get 65°30′ as its position. None of our Siddhāntas show an error of more than 1° in the sun's apogee. The error of 5½ degrees committed by Ptolemy, is very surprising. The statement of Prof. Whitney that the Hindus borrowed the figures for apsides and nodes from the positions given by Ptolemy or by some earlier Greek writers is, therefore, incorrect. He has never himself compared the positions of the apsides and nodes calculated from European tables for Ptolemy's time, or for Śaka 421 or for any other time. He himself says that finding their positions involves a very intricate and laborious calculation*. But it is not particularly difficult. Looking to Whitney's general ability, it can be said that the calculation of the places was not a difficult task for him. He has certainly, not considered the matter properly, and an inference drawn, without making proper comparison, is bound to be mistaken. The very differences of 3 to 82 degrees between Ptolemy's figures and those of our works in the positions of apsides and nodes, show that the two have absolutely no connection. The position of the sun's apogee alone will prove this. The sun's

*Translation of the Sūrya Siddhānta by Burgess, p. 283.

apogee according to the writers of our Siddhāntas has remained near about 78 degrees from Śaka 421 to this date. It is not known since how long it had remained there before the date. Different Siddhāntas differ widely from one another in respect of the places of aphelia of other planets but not in the case of the sun. Had the Hindus borrowed the positions of apsides from Ptolemy's work, how could they have changed the position of the sun's apogee from 65° to 78° ?. It will be seen at different places in this work that, while borrowing the positions of planets from other works, the authors of our works do not allow a discrepancy even in seconds. This shows that the apsides mentioned by our works have been independently calculated. Even the apsides and nodes of the authors of our own Siddhāntas differ considerably amongst themselves. This shows that even the authors of our Siddhāntas did not borrow figures from one another, but each of them found them out independently. Whitney remarks that "the Hindus were not capable enough to derive such data as the apsides and nodes for themselves or to modify or improve them when borrowed from other sources, according to the lapse of time"; but on the contrary, this very charge can be made against Ptolemy. The sun's apogee 65°30′ given by Ptolemy was correct for the times of Hipparchus who lived in 150 B. C. It shows that Ptolemy might have taken the figure without applying a suitable correction for his time. Calculation shows that the aphelia and nodes of other planets also agree with those true for the time when Hipparchus lived. It appears from this that Ptolemy might have adopted even these from the figures in use in the time of Hipparchus without applying suitable corrections. But no information is at present available to show what positions for the apsides and nodes were assumed in the time of Hipparchus or before him and hence nothing can be said with certainty about this. It is left to the readers to consider, if the Hindus could have borrowed the positions of apsides and nodes either from Ptolemy or from earlier Greeks* when the figures for apsides and nodes given by Ptolemy were so erroneous and had no similarity with those obtained from Hindu works, and when it is not known at present what positions were accepted in Ptolemy's time. Ptolemy's figures showing the positions of apsides and nodes which were possibly borrowed by him from Hipparchus, and those derived from our old works differ from 3° to 30° in the case of the apsides and from 4° to 82° in the case of nodes. If we assume that the Hindus adopted these figures in their works after applying a suitable correction to Hipparchus figures, basing their calculation on the changes in both, which took place within a period of 650 years, which elapsed from the time of Hipparchus (150 B.C.) to Śaka 421 (500 A.D.), the difference ought to have been uniform throughout, but it is not so, and had they assumed the difference to be due to their motion in 650 years they would have given a larger figure for the motions of the apsides and nodes, but they mention a figure which is less than 1° in 13000 years. This shows that the Hindus did not borrow the apsides and nodes even from the works of the Greeks who lived earlier than Ptolemy. There is another proof that the authors of our Siddhāntas found out the positions of apsides and nodes true for their times independently. There are no means to know, if the original Sūrya-Siddhānta had given revolutions of apsides and nodes in a Kalpa or not. The Pañcasiddhāntikā does not give these. First Āryabhaṭa has not given also, but he has given their positions for his time. This shows that he must have come to know that the motions of apsides and nodes, if they had any, were extremely slow, but he has not given the revolutions of their motions in a yuga, as they could not be detected in a short period. Bhāskarācārya, while

*This remark is based on Whitney's statement.

describing the method of finding the position of the sun's apogee at a given time, observes about its motions as follows :—

उच्चस्य चलनं वर्षशतेनापि नोपलक्ष्यते किंत्वाचार्यैश्चंद्रमंदोच्चवदनुमानात् कल्पिता गतिः सा चैवं ।।

यैर्भगणैः सांप्रताहर्गणाद्वर्षगणाद्वा एतावदुच्चं भवति ते भगणा युक्त्या कुट्टकेन वा कल्पिताः ।।

The purport of the lines is given below :—

"The motion of an aphelion can not be detected even in centuries. But the motions of the moon's apogee do come to notice. Assuming that the sun's apogee may also have a similar motion, the author arbitrarily took such a number for revolutions as would give correct position* for the desired moment." Bhāskarācārya has written that similar method should be followed in the case of the aphelia and the nodes of other planets also. It shows that the authors of our Siddhāntas knew how to find the positions of the apsides and nodes at a particular time and they have accordingly found the figures for their revolutions. *This proves that the writers of our Siddhāntas have independently found out positions of the apsides and nodes for their times.*

VARĀHAMIHIRA

His Date

He was a famous astronomer, who compiled works on all the three branches of astronomy. Let us consider his probable date. He has nowhere mentioned his date explicitly. But he has already mentioned in his Karaṇa work. named Pañcasiddhāntikā that he has adopted Śaka 427 as the starting year He must have been at least 20 years old, if he had compiled the work then. It is impossible that such a work could have been written at an earlier age and from this we can take Śaka 407 as the approximate year of his birth. A line is often quoted in support of the date of his death. It runs as follows :—

नवाधिकपंचशतसंख्यशाके वराहमिहिराचार्यो दिवं गतः ।।

which means that Varāhamihira passed away in Śaka 509. It is not known if this line was originally in prose or in metric form, if in metric form, it is extremely incorrect. According to some, this line is quoted by PṚTHŪSVĀMI, the commentator of Brahmagupta. The anthor has gone through the Pṛthūdaka-commentary of the first ten chapters of Brahmagupta's Siddhānta, but he has not come across this line in it. He has not read the commentary on *Golādhyāya* and other chapters following the first ten. He is unable to say, if the line is given in this commentary or in that of Khaṇḍakhādyaka. This Pṛthūdaka lived about the Śaka year 900. If the line was written by Pṛthūdaka himself, it must have been written 400 years after Varāha and hence it requires very careful scrutiny for its acceptance in the face of Śaka 427 given by Varāha himself.

According to Prof. Weber**, it is the statement of ĀMARGJA, the commentator of Brahmagupta that Varāhamihira died in Śaka 509. He has not given the original quotation, but it must pobably be the same as above. It is, thereefor,

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*The apsides were assumed to be at the first point of Aries in the beginning of Kalpa.

** *See* footnote 293 in Weber's book.

doubtful if the line is the quotation of Pṛthūdaka or of Āmarāja. Weber has quoted another statement of Āmarāja that ŚATĀNANDA was born in Śaka 917. But the work, *Bhāsvatīkaraṇa* of Śatānanda has taken Śaka 1021 as the epochal year. There is no other well known Śatānanda. From this, Āmarāja's statement about Śatānanda appears to be quite incorrect ; and hence, if it is made by Āmarāja at all, it also deserves little or no consideration. The second point to be considered, is that Āmarāja's statement carries little weight since he lived after Śaka 917, that is 4 or 5 centuries later than Varāhamihira. Considering also the correctness or otherwise of our manuscripts, if the above quoted line be in prose, it leaves room for doubt, if it has come down to us in its exact form. It is, therefore, clear that it is better to accept Śaka 427 which is given in his own work and which leaves no room for any doubt according to planetary positions given in it, as more reliable than to say, after relying on such a quotation, that Varāhamihira died in Śaka 509. It is true that the Śaka year which is adopted by a Karaṇa work need not be the year in which the work was completed. Thus Keropant's work has given examples for Śaka 1772, though it was printed in Śaka 1782. In the same way, Varāha's work could have been completed after Śaka 427. Even then, the calculations concerning the work might have started in Śaka 427 or in about a year or two before or after it. Otherwise there seems to be no other reason for adopting Śaka 427 as the epochal year. If he was not born in Śaka 427, there was no possibility of adopting that Śaka. This shows that he was not born after Śaka 427 ; not only this but it is felt that he must have been at least 15 or 16 years old in that year, and he must have selected that year for solving examples ; and that is why the year appears in the work. There is no other probable reason for its mention in it. The mean sun's entry into Aries occurred nearabout the first lunar day of the light half of Caitra (*i.e.* amānta Vaiśākha) in Śaka 427 ; and he must have adopted the year Śaka 427, because it was convenient to calculate the mean positions of planets for the moment and to describe the method of calculating ahargaṇa from the 1st lunar day of the light half. It is just possible that the work might have been actually compiled even later. But even then, the mean sun's entry into Aries apears to have occurred near about the first lunar day of the light half in Śaka 419 before Śaka 427 and in Śaka 438 before that year. The year 419 need not be considered at all and the figure 438 has not been adopted. This shows that the work was completed before Śaka 438. The Pañcasiddhāntikā mentions Āryabhaṭa's name and his work was compiled in Śaka 421 ; hence, one may be led to raise the objection that there was hardly any possibility of Āryabhaṭa's work having become so famous in a period of 6 years ; but the objection is not worth much consideration. Varāha's work could possibly have taken 4 or 5 years more after Śaka 427 for completion. It is, therefore, not quite impossible for the well known astronomer, devoted to the same work and residing in the famous city of Avantī, to have noticed Āryabhaṭa's work or to have known his viewsr It appears for certain that in Śaka 427, Varāhamihira was old enough to be able to do calculations. If, therefore, it be supposed that he was 15 years old in Śaka 427, his year of birth comes to be Śaka 412 and if Śaka 509 be supposed to be the year of his death, his age at death comes to be 97 which is not an impossibility. The birth-year of Varāhamihira, then, from all considerations comes to be about Śaka 412. It is just possible that he adopted Śaka 427 as the starting year, because it was his year of birth. There is however, no doubt that his birth year is not later than Śaka 427..

The following verse from the work, *Jyotirvidābharaṇa*, shows that Varāhamihira was one of the nine gems at the court of Vikrama, *i.e.* near about the commencement of the Vikrama era :—

धन्वंतरिक्षपणकामरसिंहशंकुवेतालभट्टघटखर्परकालिदासाः ।।
ख्यातो वराहमिहिरो नृपतेः सभायां रत्नानि वै वररुचिर्नव विक्रमस्य ।।

The famous Varāhamihira was one of the nine gems at the court of KING VIKRAMA. *These nine gems were ;—Dhanvantarī, Kṣpaṇaka, Amarasiṃha, Śaṃku, Vetālabhaṭṭa, Ghaṭakharpara, Kālidāsa, Varāhamihira* and *Vararuci*".

It has been mentioned in this work that it was compiled by the famous poet Kālidāsa who composed the poems "Raghu", "Kumāra", etc. and the verse.

वर्षैः सिंधुरदर्शनांबरगुणै ३०६८ र्याते कलौ संमिते मासे माधवसंज्ञिते च विदितो
ग्रंथक्रियोपक्रमः ।।

This work was begun in Kali-elapsed year 3068, in the month name Mādhava.

It is stated in the verse that the work was commenced in 3068 elapsed from Kali, that is, in Vikrama Samvat 24. But it also describes the following method of finding ayanāṃśas for a particular year.

शाकः शरांभोधियुगो ४४५ नितो हृतो मानं खतर्के ६० रयनांशकाः स्युः ।।

Subtract 445 from the Śaka number (of the year concerned) and divide (the remainder) by 60, and the result would be the ayanāṃśa. Also, the first chapter contains the word मता वराहमिहिरादिमतैः meaning, 'as accepted by Varāha and others" and hence this work cannot be relied upon. If some other Varāhamihira had lived about the commencement of Vikrama era, as mentioned in this work, he must have been a different person from the compiler of the Pañcasiddhāntikā*

HIS LINEAGE, RESIDENCE, ETC.

Varāhimihira observes in Bṛhajjātaka,

आदित्यदासतनयस्तदवाप्तबोधः कापित्थके सवितृलब्धवरप्रसादः ।।
आवंतिको मुनिमतान्यवलोक्य सम्यग्घोरां वराहमिहिरो रुचिरां चकार ।। ९ ।।

उपसंहाराध्याय.

*The late Raghunāth Śāstrī Tembhūkar, an astronomer of Poona, gave me a verse about the date of Varāhamihira, which he reported to me to have taken from the Kutūhala Mañjarī, belonging to Rājārāma Vyankateś Śāstrī of Bidar. The verse runs thus :—

स्वस्तिश्रीनृपसूर्यसूनुजशके याते द्विवेदांबरत्रै ३०४२ मानाब्दमिते त्वनेहसि जये वर्षे वसंतादिके ।। चैत्रे श्वेतदले शुभेवसुतिथावादित्यदासादभूद्वेदांगे निपुणो वराहमिहिरो विप्रो रवेराशिभिः ।।

(*Meaning* :—The Brāhmaṇa 'Varāha' son of Ādityadāsa and proficient in Vedāṅgas, was born with the blessings of the god Sun, on the 8th lunar day of the light half of Caitra, in the year named Jaya, in the Yudhiṣṭhira Śaka 3042). Varāhamihira, the author of Pañcasiddhāntikā also was "son of Ādityadāsa, who got him with the blessings of the god Sun', But the year mentioned in this verse does not agree with calculation by any method whatsoever ; hence, the verse is not reliable.

"Varāhamihira, who was the son of Ādityadāsa, from whom he obtained knowledge, who was blessed with the god Sun at Kāpitthaka and lived in Avantī, compiled this beautiful 'horā' work, after studying the views of sages".

This shows that Ādityadāsa was the name of his father, from whom he mastered all knowledge. He received blessings from Sun at Kāpitthaka and was the resident of Ujjayinī. Kāpitthaka must be a place near about Avantī, and he might have lived there for some time. That he was the devotee of Sun, is apparent from the prayers chiefly offered to Sun god in the benedictory verses he has given at the beginning of all his works. The following verse from the Pañcasiddhāntikā shows that his tutor in astronomy was a preson different from his father :—

दिनकरवसिष्टपूर्वान् विविधमुनीन् भावतः प्रणम्यादौ ।।
जनकं गुरुं च शास्त्रे येनास्मिन् नः कृतो बोधः ।। १ ।।

अध्या. १.

That he was the resident of Ujjayinī can be seen from 4 or 5 of his references made elsewhere.

FOREIGN TRAVEL.

Some people are found to believe that Bhāskarācārya went to Greece to learn 'astronomy'. But, looking to his works and to those of his earlier writers, this belief appears to be quite baseless. The same remark is also made about Varāhamihira by some. But his works and Bhaṭotpala's commentary on them show that works on all the subjects deat with by Varāhamihira in his works existed in plenty in our country before him and hence he had no reason to go to a foreign country.

HIS WORKS

He has compiled works on pilgrimage (travel), marriage, mathematics (Karaṇa), Horā (astrology), and Saṃhitā (Astronomy). His famous work on the Saṃhitā branch, known as *Bṛhatsaṃhitā* was compiled by him after all other works as can be seen from his own remark made in the Bṛhatsaṃhitā.

वक्रानुवक्रास्तमयोदयाद्यास्ताराग्रहाणां करणे मयोक्ताः ।
होरागतं विस्तरतश्च जन्म यात्राविवाहैः सह पूर्वमुक्तं ।। १० ।।

अध्या १.

"I have treated in my Karaṇa work the questions of direct and retrograde motions, the rising and setting of planets and luminaries ; the work on Horā-branch which includes the description of birth in detail, has already been described along with the subjects on travel and marriage".

The work on Horā-branch, alluded to by him, in the above verse, refers no doubt, to the Bṛhajjātaka. The following verse from the Bṛhajjātaka shows that the works on marriage and Karaṇa preceded the Bṛhajjātaka while that on travel (yātrā) followed it.

अध्यायानां विंशतिः पंचयुक्ता जन्मन्येतद्यात्रिकं चाभिधास्ये ॥ ३ ॥
...विवाहकालः करणं ग्रहाणां प्रोक्तं पृथक् तद्विपुला च शाखा ॥ ६ ॥

बृ. जा. उपसंहाराध्याय.

"The group of three (subjects) which I will describe along with the subject of birth, have been given ir 25 chapters....the subject of marriage, and that of the calculation of planets, which are described independertly, form 'extensive branches"

The karaṇa work referred to in it is the Pañcasiddhāntikā itself. It does not refer to any other work compiled earlier. This consideration and the consideration of his age lead one to believe that the Pañcasiddhāntikā itself was Varāha's first work. Utpala's commentary on chapter 1, of the Bṛhatsaṃhitā, shows that his work on marriage was known as Bṛhadvivāhapaṭala. This work and his work on pilgrimage are not available at present. He has compiled a work named Laghujāṭaka on Horā branch in addition to his Bṛhajjātaka; he remarks in it,

होराशास्त्रं वृत्तैर्मया निबद्धं निरीक्ष्य शास्त्राणि ॥
यत्तस्याप्यार्याभिः सारमहं संप्रवक्ष्यामि ॥ १ ॥

" After studying the scientific works compiled on the subject of astrology (Horā), I describe their summary in Āryā metre."

CIRCULATION OF WORKS

This shows that the Laghujātaka is the abridged edition of Bṛhajjātaka. From all considerations *the order of his works* seems to be as follows :—

Pañcasiddhāntikā, Vivāhapaṭala, Bṛhajjātaka, Laghujātaka, Yātrā, Bṛhatsaṃhitā. The Laghujātaka, in this, might have been probably compiled after Yātrā and Bṛhatsaṃhitā. The works, Bṛhajjātaka and Laghujātaka are very much in use amorgst astrologers even to this day ; and both of them have been printed at Bombay, Poona, Vārānasī and other places and might have been published in several places in different scripts. Dr. Kerne has published only the text of the Bṛhatsaṃhitā and its English translation in the 5th volume of the Royal Asiatic Society. The text of the Bṛhatsaṃhitā has been published in the Bibliothica Indica at Calcutta. The Jaganmitra press of Ratnagirī has published the text of Bṛhatsaṃhitā along with its Marāṭhi translation.

COMMENTARY

Bhaṭotpala is the famous commentator of Varāha. The Bṛhatsaṃhitā and the Bṛhajjātaka being very useful works, have remained in use up to this day. Even then, it may also be said that Utpala's commentary has specially been the cause of their popularity. Utpala, in his commentary on the Bṛhatsaṃhitā, in the discussion on 'Nīrājana vidhi', remarks " commented in detail under the question of travel" which shows that Utpala has written a commentary on the work on pilgrimage. He wrote a commentary on the Laghujātaka also. Other works of Varāha do not appear to have been commented upon by Utpala. The date of Utpala's commentary comes to about Śaka

888 *i.e.* about 400 years after Varāha. His remark "others hold this view" in the commertary on Rāhucāra and at other 2 or 3 places, show that there were other commentaries on the Bṛhatsaṃhitā before Utpala's time. The commentaries on the Bṛhajjātaka by Mahıdāsa and Mahıdhara are in the Deccan College collection (*See* Nos. 341, 343 of 1882—83 A.D.).

DESCRIPTION OF HIS WORKS

A more detailed description of the Bṛhatsaṃhitā, the Bṛhajjātaka and the Laghujātaka will be given later on. A description of the Pañcasiddhāntikā, his works on mathematical-branch, has been given before in almost full details. The remaining points will be dealt with here.

A verse has already been given above which remarks, "I have described in the Karaṇa work the questions of retrograde and direct motions, setting and rising of plantets, etc." Later on he observes,

युद्धं यदा यथा वा भविष्यमादिश्यते त्रिकालज्ञैः ।। तद्विज्ञानं करणे मया कृतं

सूर्यसिद्धांतात् ।।

बृ. सं. अ. १७.

"I have incorporated from the Sūrya Siddhānta in my *Karaṇa work*, the knowledge of predicting, like the seers of the three times (past, present and future) when and how war will take place."

And all these questions have been dealt with by him in the Pañcasiddhāntikā. This remark and other proofs also show that the Pañcasiddhāntikā itself was his Karaṇa work (*i.e.* a work on practical mathematics). Nowhere ir the book has he mentioned Pañcasiddhāntikā as its name.

अष्टादशभिर्बध्वा ताराग्रहतंत्रमेतदध्यायैः ।।
भजते वराहमिहिरो ददाति निर्मत्सरः करणं ।। ६५ ।।

पं. सि. अ. १८

"Free from jealousy Varāhamihira has given this excellent short treatise on the planets comprised in 18 āryās."

In this, he calls the work as a Karaṇa and a Tantra. He has, at one more place in the Pañcasiddhāntikā, called the work a *Karaṇa* or a '*Tantra*'. Utpala has given the name of Pañcasiddhāntikā to the work. It has already been pointed out that he has translated the five Siddhāntas. He has recommended his own corrections to be applied to the mean positions of planets mentioned by the Sūrya Siddhānta.

क्षेप्याः शरेंदु १५ विकलाः प्रतिवर्षं मध्यमक्षितिजे ।
दश १० दश गुरोर्विशोध्याः शनैश्चरे सार्धसप्त ७।३० युताः ।। १० ।।
पंचद्वया २५ विशोध्याः सिते बुधे खाश्विचंद्र १२० युताः ।।

"The following corrections should be applied to mean places of planets :— 15 seconds per year should be added to Mars ; 10 to be deducted from Jupiter ; 7½ to be added to Saturn ; 25 to be subtracted from Venus and 120 to be added to Mercury.'

It has already been shown above that none of the Siddhārtas of the Pañcasiddhāntikā was compiled by Varāhamihira and these corrections prove the fact beyond doubt. Had the places and motions of planets giver in any one of them been calculated by him, there was no need of mentioning the corrections. It has been pointed out before that the elements given in Bhāsvatī karaṇa tally after these corrections are applied.

Varāhamihira has mentioned the mean places from different Siddhāntas. The explanation of eclipses is also given in different ways from different works.. However, the following verses from chapters 1 and 18 show that in mentioning them it was Varāha's intention to show that he has rectified in his work those items which the earlier authors of Tantras were unable to do.

यत्तत्परं रहस्यं भ्रमति मतिर्यत्र तंत्रकाराणां ।।
तदहमपहाय मत्सरमस्मिन् वक्ष्ये ग्रहं भानोः ।। ५ ।।
दिक्स्थितिविमर्दकर्णप्रमाणवेलाग्रहाग्रहार्विंदोः ।।
ताराग्रहसंयोगं देशांतरसाधनं चास्मिन् ।। ६ ।।
सममंडलचंद्रोदय यंत्रछेद्यानि तांडवच्छाया ।।
उपकरणाद्यक्षडयावलंबकापक्रमाद्यानि ।। ७ ।।

अध्याय १

प्रद्युम्नो भूतनये जीवे सौरे च विजयनंदी ।। ५९ ।।
भग्नावतः स्फुटमिदं करणं दृष्टं वराहमिहिरेण ।।

अध्याय १८

The above verses mean :—

(No. 5) "That subject which is the greatest mystery, which perplexes the minds of the writers of astronomical works, *viz.* the eclipse of the sun, I am going to explain in this work, dismissing all jealousy."

(No. 6) "Moreover these are contained in this work, the (rules for the calculation of the) direction, the duration, the period of total obscurity, the hypotenuse, the time of the measures (*i.e.* beginning, middle and endlng of eclipses) of the eclipses or (eventual) non-eclipses of the moon, the conjunctions and obscurity of stars and planets, the means of finding the difference in longitude."

(No. 7) "The prime vertical, the rising of the moon, the construction of astronomical instruments; the shadow of the gnomon; other useful matters; the sine of the terrestrial latitude; the sine of colatitude; the declination and other subjects."

Similarly,

(No. 59) "This Karaṇa work has been accurately compiled by Varāhamihira, since Pradyumna broke down in his efforts (over the calculation) of Mars and Vijayanandī over that of Jupiter and Saturn."

It, therefore, shows that he must have done something more than the original works included in the Pañcasiddhāntikā. The corrections to mean planets mentloned above is one of such items. There are no means to know

what the other items were. It is not, however, possible that he might have made great changes in the original. It appears that he retained those things from the five Siddhāntas which, he thought showed an agreement with experience, and those general methods which were theoratically sound in his opinion and omitted the remaining matter. It seems also possible that he must have evolved his own methods concerning the questions of 'deśāntara' (difference in longitude) calculation of chāyā (shadow) ; grahaṇa (eclipses) and chedyaka (projections).

He at first compiled the Karaṇa work. But later on his Saṃhitā works show that his attention was drawn very much to astrology and various natural phenomena, properties of matter and their utility in everyday life. Brahamagupta has crticised earlier astronomers, but has nowhere criticised Varāhamihira.* Bhāskarācārya has praised him and has taken Varāhamihira's quotations in support of his statements in a number of his works. There have been several authors who wrote on 'astronomy' as a branch of *natural science*, but it can be said that there has been no other astronomer after Varāhamihira who has himself treated several branches of natural science itself. It is a matter of pride to us that such a scholar lived in our country in such an ancient time. But while his works on astrology have been found very useful to this day, his works on Saṃhitā have neither been much studied nor been used to that extent. Had the studies of properties of matter continued on the same line without any break, the Europeans could not have surpassed us in this field. But it is misfortune of our country that the tradition was not continued.

ŚRĪṢEṆA AND VIṢṆUCANDRA

These astronomers lived sometime after Varāha and before Brahmagupta, that is, between Śaka 427 and 550. Their works are not now available. The view, that the Romaka and Vasiṣṭha Siddhāntas were either compiled by them or with the help of their works, have already been considered before.

BRAHMAGUPTA

Date

Brahamagupta writes in his work, *Brāhmasphuṭasiddhānta*

श्रीचापवंशतिलके श्रीब्याघ्रमुखे नृपे शकनृपाणां ।।
पंचाशत्संयुक्तैर्वर्षशतैः पंचभिरतीतैः ५५० ।। ७ ।।
ब्राह्मः स्फुटसिद्धांतः सज्जनगणितगोलविन्प्रीत्यै ।।
त्रिंशद्वर्षेण कृतो जिष्णुसुतब्रह्मगुप्तेन ।। ८ ।।

From this it seems that Brahmagupta compiled this work in Śaka 550 when King Vyāghramukha of Cāpa dynasty was ruling. His father's name was Jiṣṇu. Brahmagupta was 30 years old when he wrote Brahma Siddhānta in Śaka 550, which shows that his birth year was Śaka 520.

*Brahmagupta has criticised Varāhamihira for not stating that Rāhu, who envelops the moon while it enters the earth's shadow, was the main cause of the eclipse ; but this is really not a defect ; and in reality even Brahmagupta did not mean to blame him.

Place

Brahmagupta was the resident of Bhinamāla. This village is situated on the northern border of Gujarat in South Marwar, 40 miles to the northwest of Abu, between the mount Abu and the river Luni. It is now a small village. Formerly it was known as Bhilamāla or Śrīmāla. It was the birth place of poet Māgha. It was the capital of north Gujarat, when Hiuen-Thsang, the Chinese traveller visited this country in the 7th century A.D. Brahmagupta compiled his Siddhānta during the reign of Vyāghramukha of the Cāpa dynasty and he called himself Bhillamālakācārya*. Some descendant kings of the Cāvadā or Cāpotkaṭa dynasty ruled at Anhilwāda from 756 to 941 A.D. ; and even at present, they are rulers of petty states in north Gujarat. This Cāvadā dynasty must be identical with the Cāpa dynasty referred to by Brahmagupta. Hiuen-Thsang has mentioned Bhilamāla as the Capital of Gujarat about the time of Brahmagupta himself, and the traditional account that Brahmagupta was the resident of Bhilamāla, is still found in Gujarati works on astronomy. This shows that Brahmagupta may be the resident of Bhilamāla**.

His Works

The Brāhmasphuṭasiddhānta and the Karaṇa work, named Khaṇḍakhādyaka are his well known works, and in the latter he has adopted Śaka 587 as the epochal year and this shows that he compiled this work at the age of 67. He writes in the Brahma Siddhānta.

गणितेन फलं सिद्धं ब्राह्मे ध्यानग्रहे यतोध्याये ।। ध्यानग्रहो द्विसप्तत्यार्याणां न लिखितोऽत्र मया ।।
अध्या. २४.

" Since the chapter named 'dhyānagraha' gives sure results of mathematics, I have not included the chapter, dhyānagraha, consisting of 72 verses in this (Siddhānta)."

It therefore shows that he had written a chapter named 'dhyānagraha consisting of 72 couplets and he had mentioned some results in it. He states that it has not been included in the Siddhānta work, and it is not at present available as an independent work. It is not, therefore, known if it contained any astrological deductions or some results like those of Saṃhitā works ; but the above couplet suggests that it was a very important chapter and meant to be taught secretly to students.

Other Versions of Brahmasiddhānta

A couplet is already given on page 4 which states that the science of astronomy is being described in a correct form in it, since, the science, as revealed by Brahmā, has become loose on account of lapse of time. There is a well-known Brahma Siddhānta by Śākalya, which is supposed to have been described by god Brahmā to Nārada ; but it has already been pointed out on page 50 that it was not compiled before Śaka 743, and that it does not resemble the Brahmagupta Siddhānta in respect of the numbers of revolutions and other elements given by Brahmagupta or in other respects. This shows that the two are not related at all. One of the 'Purāṇas' known as " Viṣṇudharmottara Purāṇa †" contains a Brahma Siddhānta. Bhototpal has taken

*Varuṇa, the commentator of Khaṇḍakhādyaka, has given him some such title as Bhillamālakācārya, and it is found at the end of some of the manuscripts.

**Indian Antiquary, XVII, page 192, July 1888.

†There is a copy of this in the Deccan College collection.

in Bṛhatsaṃhitā a number of couplets from Brahmagupta Siddhānta and he has referred to all such places in such words as 'Brahma Siddhānta' or 'so says Brahmagupta'. Nowhere has Utpala referred to these couplets as 'from Brahma Śiddhānta of Śākalya' or 'from Brahma Siddhānta included in Viṣṇudharmottara Purāṇa'. This shows that the two Siddhāntas, it existing then at all, were not much known ; and according to Utpala, at any rate the Brahmagupta Siddhānta was the one compiled by Brahmagupta. Even Brahmagupta calls his Siddhānta everywhere Brahmasphuṭa Siddhānta or simply Brahmasiddhānta. The author has also called this Siddhānta 'Brahma Siddhānta' for convenience in this work.

Elements

The numbers of revolutions and other elements mentioned in the Brahma Siddhānta are given below :—

	In a Kalpa which is a period of 4320000000 years			
	Measures like sāvana days, etc.	Revolutions in longitudes	Revolutions of	
			apsides	nodes
Revol. of stars . . .	1582236450000			
The Sun		4320000000	480	
Sāvana days . . .	1577916450000			
Moon		57753300000		
Moon's apogee . . .		488105858		
Moon's ascending node .		232311168		
Mars		2296828522	292	267
Mercury		17936998984	332	521
Jupiter		364226455	855	63

	In a Kalpa which is a period of 4320000000 years			
	Measures like sāvana days, etc.	Revolutions in longitude	Revolutions of	
			apsides	nodes
Venus		7022389492	653	893
Saturn		146567298	41	584
Solar months . . .	51840000000			
Intercalary months . .	1593300000			
Lunar months . .	53433300000			
Tithis	1602999000000			
Suppressed tithis . .	25082550000			

	d	gh	p	vip	pvp
Length of the year =	365	15	30	22	30

All the measures in this table are given for a *Kalpa*. No number can be found which can completely divide the numbers denoting the revolutions of all planets, and hence, according to this Brahma Siddhānta the mean planets cannot all come together at one place, at any moment other than at the beginning of Kalpa. All the planets come together by mean motions at the beginning of *Kaliyuga* according to the first Ārya Siddhānta or the two Sūrya Siddhāntas, but they are not so conjoined according to the Brahma Siddhānta. This Siddhānta does not, like the modern Sūrya-Siddhānta, assume any period spent over creation. According to this, the moment of commencement of the Kalpa coincides with that of the planets starting to move.

Length of Year

The first thing to be remembered is that the length of the year, *viz.* 365d 15g 30p 22vip 30pvp, as adopted by this Siddhānta, is less than that adopted by any Indian Siddhānta except the Puliśa and Romaka of the Pañcasiddhāntikā. It has been clearly pointed out in the discussion of the ancient and modern groups of five Siddhāntas that the Puliśa and Romaka Siddhāntas of Pañcasiddhāntikā were not in use in Brahmagupta's time. The *first* Ārya Siddhānta and *original* Sūrya Siddhānta were in use in his time. Of them, Brahmagupta's length of the year is shorter than that of the original Sūrya Siddhānta by 67½ vipalas and by 52½ vipalas than that of the first Ārya Siddhānta. This difference appears to be very small, but because of this (small) variation the moment of the mean sun's entry into Aries in Śaka 540, according to Brahmagupta, occurred 54gh 14⅛ pals earlier than that according to the first Ārya Siddhānta and 54gh 43⅞ pals earlier than that according to the original Sūrya Siddhānta. What then is the cause of this variation ? The cause seems to be only one that he assumed the solar ingress into Aries to have occurred on the day on which the day and night were of equal length, *i.e.* on the equinoctial day, when the sun rises on the horizon exactly in the east. This moment of the solar ingress is nothing but the entry of the sun in the sāyana (tropical) sign of Aries. The moment of the sun's actual entry into the tropical sign of Aries on or about the day when Brahmagupta might have taken actual observation, coincided with the moment of the same phenomenon as calculated from Brahma Siddhānta. The moment of the true sun's entry into Aries in Śaka 509, as calculated from Brhamagupta Siddhānta comes to be 56gh—40p after mean sunrise at Ujjayinī on Tuesday, the 3rd lunar day of Caitra Śukla, the 18th March 587 A.D. ; and the time of the entry of the sun into sāyana Aries (*i.e.* sun's longitude being $0^s\ 0^\circ\ 0'$) comes to be the same moment on the same day during that year.*. Brahmagupta was born in Śaka 520. He might have begun the taking of observations from about Śaka 540. Hence, the calculation, according to Brahmagupta, for the year Śaka 540, shows that the apparent Aries ingress appears to have occured at 57gh—22p (after sunrise) on Saturday, the first lunar day of the dark half of Caitra and the tropical

*The sāyana calculations have been made with Keropant's Planetary Tables. As these Tables are not quite accurate, the phenomenon will perhaps be found to occur a year earlier or later. Similarly, the secular equation has not been applied to the sun's place in the above calculation, it would come to about two minutes, which may cause a variation of a year or two.

longitude of the sun comes to be 0^s 0° 30′, which shows that the sāyana Aries ingress took place about 30gh before the moment calculated from Brahma Siddhānta. But the sun's declination increases only by 12 minutes in 30 g haṭis nearabout the equinoctial time. Hence, in Śaka 540, the sun must h ave been to the north of the equator by 12 minutes at the moment of the sun's entry into Aries according to Brahma Siddhānta, and if the sun had cometo the first point of Aries (Meṣa Saṃkramaṇa) according to Brahmagupta, at sunrise, the sun's centre would have appeared 12 minutes to the north of the east point. But it is not that the equinox always takes place at the time of sunrise. Any one experienced in the taking of observations will easily admit that an error of 12 minutes arc is possible because errors of some minutes can occur in the determination of directions and also the fact that the instruments of observations used to be crude ; and these considerations lead me to be convinced that he must have taken the sun's entry into the tropical sign of Aries as the moment of Meṣa Saṃkrānti. He ovserves in the Siddhānta,

यदि भिन्नाः सिद्वांता भास्करसंक्रांतयोपि भेदसमाः ।।
स स्पष्टः पूर्वस्यां विषुवत्यर्कोदयो यस्य ।। ४ ।।

अ. २४.

"If Siddhāntas are different, so must be the moments of the sun's entry into signs ; but when the sun is on the equator, it is actually seen rising exactly in the east."

The purport of the verse is that the moments of the sun's crossing as seen in the sky will not appear* to be occuring at different moments. This refers to the sun at the time of sunrise on the equinoctial day. It is clearly the place of the tropical sun and Brahmagupta has clearly recorded the place by actual observation. Brahmagupta did not know that the equinox has motion and even if it were known before his time, he undoubtedly did not take it into consideration. Hence, he does not differentiate between the sāyana place of the sun and that found by calculation from his works (*i.e.* nirayaṇa). He attempted to see that the place calculated by his work will exactly tally with that of the tropical sun ; but this was a correct step only so far as his own time was concerned. The reason for this is that though equinox occurred 54 ghaṭis before the calculated time, but yet he could not ignore the traditional belief that the mean sun was at the first point of Aries at the commencement of the Kaliyuga (*i.e.* at sunrise, on Friday, according to his view). He, therefore, distributed the error of 54 ghaṭis over the period of 3730 years (the period between the commencement of Kaliyuga and the date of compilation of the Brahma Siddhānta) and he so effected the adjustment that his work should give the moment of equinox to tally with the entry of the sun into the tropical sign of Aries, that is, the moment when the sun actually appeared to rise exactly in the east. This adjustment diminished the length of the year only by a few vipalas. If he had not to encounter the difficulty of distributing the error over the period from the Kaliyuga to his own date, and if he had just considered how much earlier than a particular date the equinox had begun to occur in his time, he would have done one of the two things—accepting, for the length of a year, the measure of the tropical solar year, *viz*. 365d 14gh 32p, or to retain the traditional length of the year and to assume some motion for the equinox. He compiled the work *Khaṇḍakhādyaka* 37 years after the

*It is because of this kind of disagreement that he remarks " Brahma Sidhānta is the only real siddhānta, while others are more compilations " and often criticises other siddhāntas. The Saṃkrānti according to others, occurs later by one day than according to his work.

Siddhānta and he adopted in it the length of the year given by the original Sūrya Siddhānta. This shows that he must have inclined to adopt some motion for the equinox after retaining the length of the year once adopted or even after being convinced that he must adopt, the actual measure of the tropical year, as the length of the year ; he was not bold enough to discard the traditional length of the year and to alter the one already adopted by him while compiling the Siddhānta. Bhāskarācārya has remarked " how is it that proficient astronomers like Brahmagupta have not mentioned the equinox* ?" . It shows that Brahmagupta's original works make no mention of the equinoctial motion.

Sāyana

Whether the almanac should follow the sāyana or the nirayaṇa system is at present a matter of controversy. A point favourable to the followers of the sāyana system is noticeable in the above discussion, and it is that it was Brahmagupta's original view that the sun's entry into a tropical sign was the actual '*saṃkramaṇa*' and it was his desire to alter the length of the year, which he did accordingly. Had he carried on observations throughout his life and compared the results, it was not impossible for a scientist like him to hit upon the correct measure of the tropical year. It may be that he might have come to know it and still was not bold enough to discard the traditional one. The reason for his measure of a year which is shorter than that of others, has not been explained by the author because he was a follower of the sāyana system. Even the staunchest follower of the nirayaṇa system will have to admit its corrections.

Correcting the Planetary Elements and Observations

The numbers showing the revolutions of planets etc., as given by the Brahma Siddhānta are somewhat different from those of the other Siddhāntas. However, the comparison of mean places of planets in Śaka 421 obtained from the Brahma Siddhānta with those of modern European works (page 63) shows that there is not much difference between them. It shows that Brahmagupta adjusted the numbers of planetary revolutions so that the calculated planetary positions for his time would agree with observations. The result of the comparison of apsides and nodes made on page 68 above also shows his independent research in that direction. Hence, the length of the year, the numbers showing revolutions of planets, nodes and apsides, point to the fact that Brahmagupta was an independent research worker who used to take observations for himself ; and this is the main important factor in astronomy. His works reveal at several places the spirit of independence and self-resp expected of such a personality. He says in the Chapter on true places,

ब्रह्मोक्तमध्यरविशशितदुच्चतत्परिधिभि: स्फुटीकरणं
कृत्वेवं स्पष्टतिथिर्दूरभ्रष्टान्यतंत्रोक्तै: ।। २१ ।।

अ. २.

" The true places obtained from the element like epicycles, aphelia and the mean sun and the mean moon, as mentioned by Brahmasphuṭasiddhānta give the correct tithi ; that obtained from other tantras is far from accurate."

*See Golabandhādhikāra—commentary on couplets 17-19.

He maintains here that the tithi calculated from other tantras is far from accurate and that the tithi calculated on the basis of the sun and the moon according to Brahma Siddhānta is correct.

आर्यभटस्याज्ञानान्मध्यममंदोच्चशीघ्रपरिधीनां ।।
न स्पष्टा भौमाद्याः स्पष्टा ब्रह्मोक्तमध्याद्यैः ।। ३३ ।।

अ. २.

"The true places of Mars and other planets calculated from the ignorant Āryabhaṭa's work giving mean positions of planets, aphelia and epicycles. prove to be wrong, they are found correct when calculated from the mean positions and other elements given by Brahma Siddhānta."

Here he maintains that the positions of Mars and other planets are correct when calculated from the aphelia, epicycles and mean planets according to Brahma Siddhānta but are incorrect according to Āryabhaṭa. There are many such instances showing his pride. This pride has, in some cases, run to such excess, that one cannot help feeling that it is little short of arrogance. He has appended in his Siddhānta an independent chapter, named, 'dūṣaṇādhāya' (No. 11) consisting of 63 couplets. Some of the charges levelled against Āryabhaṭa in it show sheer obstinacy on his part.

Subject matter of Brahma Siddhānta

He has incorporated in the first ten chapters of his Siddhānta, the chapters which are usually found occurring in almost all the Siddhāntas and been enumerated in the 'Introduction of this book'. But he has treated many more subjects in the next 14 chapters and they are very important. One of them is the chapter of criticism. One deals with *arithmetic* and another with *algebra*. Yet another describes *instruments*. Most of the remaining chapters are devoted to the theory underlying the subjects dealt with in the first half. The 12th chapter is devoted to arithmetic, mensuration etc. the56 couplets of which, include almost all the questions dealt with in *Bhāskarācārya's 'Līlāvatī'* The 18th chapter mainly treats of algebra, and contains 102 couplets, but nowhere does it actually mention the word algebra. The chapter is entitled '*Kuṭṭaka*'. It contains a number of subjects found in Bhāskarācārya's 'Bījagaṇita' (algebra). It contains a chapter headed '*Kuṭṭaka*' and it is given, mainly for being used in the calculation of mean places of planets etc. in astronomy. The Brahma Siddhānta has 24 chapters and contains 1008 Couplets.

Commentary

The Deccan college collection has a copy of the commentary by PṚTHŪDAKA on the first ten chapters. Colebrooke has recorded that he had obtained the complete commentary. Colebrooke translated the portions dealing with arithmetic and algebra from the Brahma Siddhānta into English in 1817.

Interpolation and Yogas

Brahmagupta has mentioned the number of verses at the end of every chapter. He seems to have taken this precaution, because he knew from

experience that changes are often made later in the original. In spite of this precaution there appears to be a discrepancy in respect of a few couplets in the work. Three couplets are actually found in the book without any commentary but they are not found at all in the commentary by Pṛthūdaka. One of the three couplets in the chapter on true places is particularly noteworthy since it deals with Viṣkambha and other yogas. It describes the method of calculating yogas, but it is not found in the annotated edition. One is, therefore, inclined to believe that Viṣkambha and other 26 yogas which form a part of the present almanac, did not exist in Brahmagupta's time, that is to say Vyātipāta, Vaidhṛti and other yogas did not exist in his time. They are not given even in the Pañcasiddhāntikā. This point will be discussed elaborately in the study of almanacs.

Khaṇḍakhādya

It is now proposed to review briefly his work 'Khaṇḍakhādya'. The name 'Khaṇḍakhādya' is strange and the object of giving such a name is not known. This has two parts Pūrva (first) and Uttara (second). The first part consists of 9 chapters which contain 194 couplets. The second par consists of 5 chapters comprising of 71 couplets. Brahmagupta observes in part one, at the very outset ;

वक्ष्यामि खंडखाद्यकमाचार्यार्यभटतुल्यफलं ।। १ ।।

प्रायेणार्यभटेन व्यवहारः प्रतिदिनं यतोऽशक्यः ।।

उद्वाहजातकादिषु तत्समफललघुतरोक्तिरतः ।। २ ।।

"(1) I compile the work, Khaṇḍakhādya, which gives results equivalent to those given by the great scholar, Āryabhaṭa (2) Since it is impossible to carry on every day affairs with Āryabhaṭa's work, this work is being compiled so as to give easily equally accurate results relating to matters like birth, marriage and the like."

In these verses he states that he is compiling a Karaṇa work, the calculations from which give equally correct results, or in other words which would give places of planets similar to those obtainable from the Āryabhaṭa's work which is impossible to use in day-to-day life. The Khaṇḍakhādya has adopted the length of the year (365^{d}—15^{g}—31^{p}—30^{vp}) given by the original Sūrya Siddhānta and not that of the Ārya-Siddhānta ; and hence, he had to assume the beginning of the yuga at midnight and not at sunrise as assumed by him in his own Siddhānta, or as in the Ārya Siddhānta. The epoch in Khaṇḍakhādya is Śaka 587, and the apparent first lunar day of the light half of Vaiśākha (according to the 'amānta' system) falls on Sunday in that year. The epochal positions in it are true for the midnight of Saturday, the new moon day of amānta Caitra *i.e.* for the midnight preceding Sunday ; and the ahargaṇa is to be calculated from that moment. The mean Aries Ingress according to the original Sūrya

Siddhānta falls at 12^{g}—9^{p}* on the same Saturday. The epochal positions given are as follows :—

	s	°	′	″		s	°	′	″
Sun	0	0	32	22	Mercury	9	0	44	49
Moon	0	9	9	43	Jupiter	6	4	25	16
Moon's apogee	10	8	28	9	Venus	10	0	19	14
Rāhu	0	18	47	23	Saturn	9	6	41	16
Mars	3	10	13	6					

If the places of planets, true for the midnight of Saturday, the Caitra Amāvasyā of Śaka 587, be calculated on the basis of the numbers of revolutions and other elements given before on page 23—from the original Sūrya Siddhānta, all of them except the moon's apogee and node, are found exactly to agree with the above positions. They do not agree with those calculated from the Ārya Siddhānta. It appears from this that the Khaṇḍakhādya-Karaṇa agrees with the original *Sūrya Siddhānta* with respect to all items like the length of the year, the initial moment for computing ahargaṇa and almost all the epochal positions. The revolutions of the moon's nodes are not met with in the original *Sūrya Siddhānta*. The place of moon's apogee does not agree with that of the original Sūrya Siddhānta, but it does not also agree with those of the Ārya Siddhānta or the Brahma Siddhānta. The moon's node too does not agree with either of the last two works. As the length of the year and the initial moment of the year adopted for Khaṇḍakhādya were different from those adopted in the Brahma Siddhānta, it is clear that it was no use adopting for Khāṇḍakhādya the moon's apogee and node adopted in the Brahma Siddhānta. It is true that the Khaṇḍakhādya does not agree with the Ārya-bhaṭa Siddhānta completely ; still, as some of the elements in the Āryabhaṭiya were equal to those in the original Sūrya Siddhānta, the mean positions of planets calculated from Khaṇḍakhādya for Śaka 587, almost resembled those rom the Ārya Siddhānta.

Brahmagupta, observes in the very beginning in the latter portions of the Khaṇḍakhādya, that he would describe the method of finding apparent places of planets because those calculated from Āryabhaṭa's work did not agree with observation. On this, Varuṇa, the commentator, remarks, "Brahmagupta has declared that he was going to compile a work as good as that of Āryabhaṭa, and he did the same in the first half of the work. In the second half he has mentioned an equation from his own Siddhānta to ensure results agreeing with observation. Now only those things which have not been mentioned therein, should be accepted from Āryabhaṭa's Karaṇa work". This remark and other chapters in the second half show that he has made only such changes while compiling the Khaṇḍakhādya as would give accurate results comparable by observation. He has borrowed the following important items from Āryabhaṭa's work ; the length of the year, mean motions of planets, their epochal positions and the moment of the beginning of yuga. The above remark of Varuṇa and other things show that Āryabhaṭa's work, referred here, is not his Siddhānta now available, but this Karaṇa work.

*It has been mentioned in the account of Varāhamihira that an epoch wherein the moment of mean Aries Ingress nearly coincided with the moment of the new moon was selected as a convenient moment by the Pañcasiddhāntikā also. The two resemble each other in other respects also.

It is really strange that instead of compiling a Karaṇa work equal in merit to his own Siddhānta, he porposed to compile a work and for the most part did compile one equal in merit to that of a staunch rival like Āryabhata on whom he had showered a shower of criticism. There are two reasons for this, one of them must be the fect that Āryabhaṭa's work might have been so popular that he was unable to ignore it and the second reason was that in Śaka 587 when he compiled the Khaṇḍakhādya, the moment of Aries Ingress according to his own Siddhānta occurred 55gh—36$\frac{6}{8}$pals before that of the original Sūrya Siddhānta and 54gh—55$\frac{2}{8}$ pals before that of Āryabhaṭīya. And because of this much difference, the two works would show different intercalary months. The difference in intercalary month and the occurrence of the saṃkrānti a day earlier, arethings easily noticeable even by an ignorant person; and these created an unfavourable public opinion with regard to the introduction of the mesure of his own Siddhānta. These two reasons, it appears, could not make him bold enough to compile a *'karaṇa'* which would be equal in merit to his own Siddhānta, when Brahmagupta could not introdus his own year—measure, because his saṃkrānti differed by about less than a day, it is worth considering how dificult is would be to bring into use either Keropant's almanac, whose saṃkrānti occurs about 4 days ealier than that of the old works or the sāyna almanac, whose saṃkrānti takes place about 22 days earlier

Commenmentaries on Khaṇḍakhādya

Varuṇa and Bhaṭotpala have written commenmentaries on Khaṇḍakhādya. Pṛthūdaka too is likely to have written one, but it is nowhere available. One more incomplete commentary has been found which does not mention the name of the commentator; but he appears to be one from Kashmir as can be seen from the Śaka year 1564 adopted for solving examples, and from the fact that the corrections adopted for longitudes of places and the ascensional differencess refer to Kashmir. The Deccan college collection has got a copy of the work entitled *Pañcāṅga Kautuka* (No. 537 of 1875-76 A.D.) which gives tables and methods of calculating figures for almanacs very easily. It has adopted Śaka 1580 as the epoch and the whole calculation has been made with the help of Khaṇḍakhādya. It does not mention that it is compiled in Kashmir; but it was found in Kashmir and it was made use of the popular local era prevalent in Kashmir. It clearly shows that the author belonged to Kashmir. It also shows without doubt that the Karaṇa, Khaṇḍakhādya, was in use in Kasmir till Śaka 1580; and from the three above mentioned commentaries on Khaṇḍakhādya and from the fact that the copies of the Pañcāṅga Kautuka' in the poona college collections were found in Kashmir, it is felt that it must be still in use in that province. Bhāskarācārya has refered to Khaṇḍakhādya. Albiruṇī, (Śaka 950) had obtained the Khaṇḍakhādya and quoted from it.

Spread of Brahma Siddhānta

The fact that Brahmagupta complied Khaṇḍakhādya as a work different from his own Siddhānta shows that he was not sure that he would get any follower for the Siddhānta; and it is natural, as can be seen from following well known remark of Kālidāsa.

आपरितोषाद्विदुषां न साधु मन्य...विज्ञानं ॥

"No performance should be regarded as excellent, until it satisfies the learned".

He compiled the Khaṇḍakhādya at the age of 67. His Siddhānta might not have come into actual use till then and he must have compiled Khaṇḍakhādya after being disappointed to see that he had no followers even when so many years of his age had elapsed. Very few of the great researchers are fortunate enough to see their researches bear fruit in their own lifetime. It is not very creditable to him that instead of leaving the future to decide for itself, he disregarded his own thesis ; but is it possible that the best work of such a master mind would fail to satisfy scholars ? The astronomer Bhāskarācārya who was as great as he (Brahmagupta) has in fact recognized his work. Also two more Karaṇa works compiled before Bhāskarācārya are found to have followed the Brahma Siddhanta. All of them have mentioned one additionnl correction to the plantary places calculated from Brohma Siddhānta. This correction is first noticed in the "*Rāja Mṛgāṅka Karaṇa*' compiled in Śaka 964. But the author came across an example in which the Brahma Siddhānta was found to have been used in its original form without any correction.

Original Form

The *Uttarapurāṇa*, a Jain work by Guṇabhadra found in the Poona college collection (No. 289 of 1883-84), states the date of its compilation in the followiag lines :—

शकनृपकालाम्यंतरविंशत्यधिकाष्टशत ८२० मिताब्दान्ते ।।
मंगलमहार्थकारणी पिंगलनामनि समस्तजनसुखदे ।। ३५ ।।
श्रीपंचम्यां बुधार्द्रायुजि दिबसवरे मंत्रिवारे सुधांशौ
पूर्वायां सिंहलग्ने धनुषि धरणिजे वृश्चिकार्कौ तुलागौ ।।
सूर्ये शुक्रे कुलीरे गविच सुरगुरौ

"(This work was completed) on Thursday the 5th lunar day, in the auspicious year of Pingala saṃvatsara, numbering 820 of the Śaka era when the planets were occupying the signs mentioned herein."

The planetary positions dercribed in the verses were as follows :

Sun	—Occupying	'Kulīra' (Cancer)	Jupiter	in Gau	(Taurus)
Moon	— ,,	Pūrvā (Bhādrapadā)	Venus	,, Kulīra	(Cancer)
Mars	— ,,	Dhanuḥ (Sagittarius)	Saturn (Ārki)	,, Scorpio	
Mercury	— ,,	Ārdrā nakṣatra	Rāhu (Agu)	,, Libra	

Śaka year 819 (elapsed) was known ar Pingala. The elapsed year 819 is the same as the current year 820. This at first gives rise to the doubt whether 819 should be taken for calculation or 820. Similarly, the verse does not mention any month or a half-month, but simply the tithi. The day is no doubt given as "*mantri*" *vāra*. It is conjectured that it may either be a Thursday or even a Friday. But the verse mentions the positions of all planets, and the best way to determine the *vāra* is to find out that day for which these planetary positions would be found to be simultaneonsly true. After attempting the calculations for a number of days in the two years, Śake 819 and 820, the author has found Amānta Āṣādha Kṛṣṇa 5, Śaka 818 elapsed i.e. Thursday the 23rd June, 897 A.D. as the day on which the given positions of planets appear to be true for the period between the sunrise and about 24 ghatis after it.

The verse gives Leo as the rising sign, whose duration on that day was the period between 4—9 ghaṭis after sunrise. This planetary condition is impossible for any day other than this in these two years. The moon's position mentioned in the verse, is not found to be true for any other day being earlier or later by one day. The object of mentioning this here is that these planetary positions agree only if the length of the year given by Brahmagupta in his Brahma Siddhānta be accepted and by that of no other Siddhānta. The sun, according to the Sūrya Siddhānta, appears to belong to Gemini on Thursday, the 5th lunar day of Āṣāḍha (Kṛṣṇa), and goes in to Cancer at about 5 ghaṭis after sunrise, on Friday. By no other Siddhāntas does it appear to be occupying Cancer on Thursday. The saṃkrānti, according to Brahma Siddhānta, appears to occur 61gh 31pal earlier than the saṃkrānti of the modern Sūrya Siddhānta in that Śaka year. Similarly, even Mars appears to be occupying the sign of Capricorn on Thursday according to the modern Sūrya Siddhānta and that of Sagittarius according to the Brahma Siddhānta. In short, the planetary positions are seen to agree quite well according to Brahma Siddhānta and even the consideration of the matter from several points of view leaves no doubt* about it. It proves beyond doubt that the Brahma Siddhānta was in use in its original form in Śaka 819. This old work was compiled in the Deccan when the King Akālavarṣa of Rāṣṭrakūṭa dynasty was ruling the Deccan. From this it appears that the Brahma Siddhānta was in use in its original form in the Deccan in Śaka 819. The corrections in it have been introduced by some one else later on.

Corrections

Varuṇa's commentary on the Brahma Siddhānta appeared about Śaka 962. It does not refer to any corrections. The work Rājamṛgāṅkakaraṇa was compiled in Śaka 964 and it mentions the correction. It appears to have been first introduced then. The corrections include that for even the sun. This correction has changed his length of the year from the original Brahma Siddhānta viz. from $365^{d}—15^{gh}—30^{pal}—22^{vip}—30^{pvp}$ to $365^{d}—15^{gh}—31^{pal}—17^{vks}$ that is, it is greater than that of the first Āryabhaṭa by about 2 vipalas. The worry of the Brahmapakṣa compiled after this date are found to be in conformed with the corrected Brahma Siddhānta. The Rājamṛgāṅka compiled in Śaka 964 is the first of such Karaṇa works. The second one is the Karaṇa work named 'Karaṇa Kamalamārtaṇḍa' compiled in Śaka 980. The next one, compiled after this in Śaka 1105 is the Karaṇakutūhala of Bhāskarācārya. The Mahādevī Sāraṇī, a work on planetary calculations, compiled in Śaka 1238 and the two works Kheṭakasiddhi and Candrārkī of the astronomer Dinakara and compiled in Śaka 1500, conform to the corrected Brahma Siddhānta. Of them, the Karaṇakutūhala is still in use in some places. The author of Grahalāghava has borrowed some positions of planets as in accordance with the Brahmapakṣa, and these have been taken from the Karaṇakutūhala. The Brahma Siddhānta might have remained in use in its original form up to Śaka 1000 at the most. It may have gone out of everyday use after Bhāskarācārya. Not only that, but because Bhāskarācārya's Siddhānta Śiromaṇī could serve the purpose as efficiently as the Brahma Siddhānta, it appears that Brahma Siddhānta itself might have gone out of use gradually. The quotations from he Brahma Siddhānta are rarely found in works compiled after Bhaskarā-

*The original verse as given in this book is very incorrect. This verse and the one corrected by me along with its explanation, may be seen on page 429—30 of Prof. Bhandarkar's Report on the search for Sanskrit manuscripts for the year 1883—84.

cārya. The work Brahma Siddhānta is at present not found anywhere in Mahārāṣtra, and the same may be true of other provinces as well.

Condition of Astromomy

There is no harm in saying, on the whole, that all the branches of the system which go to make the science of astronomy in our country, appear to have been completely established in the time of Brahmagupta. The necessary variations in the positions of planets were made from time to time later on. It can safely be said that no special reform or.research was afterwards made in the system except that of the equinoctial motion. It has already been pointed out above that Brahmagupta was an independent thinker as far as the revolutions of planets, the aphelia and nodes were concerned. The elements concerning the calculations of the true places of planets appear to be his own. Even in 'tripraśnādhikāra' (Adhikāra on three problems) he appears to show a greater skill than earlier writers. He has described the instruments of observation and it is my opinion that the "*turīyayantra*" (the Quadrant instrument) was his invention. The subject of Algebra is not found in any of the earlier works, which shows that he may probably be its originator. Sūryadāsa, the son of Jñyānarāja, the author of the work, Siddhānta-Sundara, wrote commentary in Śaka 1460 on Bhāskarācāryas Algebra. He regards Āryabhaṭa as the oldest writer on Algebra. The work of Āryabhaṭa I may be said to contain no discussion on Algebra ; but that of Āryabhaṭa II does contain it. But it will be shown later that this work is more modern than that of Brahmagupta. Hence the information available at present leads one to conclude that Brahmagupta was the first writer on Algebra. He has not recorded in his work any boastful remarks in the chapter on Bījagaṇita that it was he who discovered the subject anew.From this it can be conjectured that the subject might have been known even before his time. But books are not available. Brahmagupta, was on the whole, a very ingenious research worker. Even a scholarlike Bhāskarācārya has praised him thus "May the work of jiṣṇuja (i.e. the son of Jiṣṇu, Brahmagupta) who is the supreme mathematician, succeed". Similarly, at another place, he remarks, "when after a long lapse of time, a great deal of discrepancy will be caused, men of genius possessing the ability of Brahmagupta, will come to birth, and studying the planetary motions evolved by Brahmagupta, will compile work on these scieencs". It is quite proper that he has been acclaimed as "a great discoverer of (correct) positions and motions of planets and a very intelligent author of scientific works."

LALLA (ABOUT ŚAKA 560)

Works

A work, 'dhīvṛddhidatantra', on planetary calculation stands to his credit. Sudhākara Dvivedī, procured it, and got it printed in Vārānasī, in 1886 A.D. He has written a Muhūrtawork, named 'Ratnakośa'.

Date

Lalla has not mentioned his date or place of his residence. In the chapter on mean places, in Dhīvṛddhidatantra, he remarks,

विज्ञाय शास्त्रमलमार्यभटप्रणीतं । तंत्राणि यद्यपि कृतानि तदीयशिष्यैः ॥
कर्मक्रमो न खलु सम्यगुदीरितस्तैः । कर्म ब्रवीम्यहमतः क्रमशस्तु सूक्ष्मं ॥ २ ॥

"Although his disciples, after completely studying the scientific works by Āryabhaṭa, have compiled the "*tantra*" *works*, they have not described the methods of calculation in proper manner. Hence I am properly describing in brief the methods".

He has mentioned, in the Uttarādhikāra, corrections to be applied to planets obtained from the Āryasiddhānta. They are :—

शाके नखाब्धि ४२० रहिते शशिनोक्षदस्त्रै २५ स्तत्तुंगत: कृतशिवै ११४ स्तस: षडंकै: ॥ ६ ॥
शैलाब्धिभि: ४७ सुरगुरोर्गुणिते सितोच्चात् शोध्यं त्रिपंचकु १५३ हते भ्रषराशि २५०
भक्ते ॥ १ ॥
स्तंबरेमांबुधि ४८ हते क्षितिनंदनस्य सूर्यात्मजस्य गुणितेबरलोचनै २० श्च ॥
व्योमाक्षिवेद ४२० निहते विदधीत लब्धं शोनांशुसूनुचलतुंगकलासुबृद्धिं ॥ १९ ॥
इति...ग्रहकर्म दृकप्रभावत् ॥ २० ॥ आसीदशेषबुधवंदितपादपद्य:...... ॥
शाम्बस्ततोजनि जनेक्षणकैरवेंदुर्भट्टस्त्रिविक्रम इति प्रथित: पृथिव्मां ॥ २१ ॥
लल्लेन तस्य तनयेन शशांकमौले: शैलाधिराजतनयादयितस्य शंभो: ॥
संपूज्य पादयुगमार्यभटाभिधानसिद्धांततुल्यफलमेतदकारि तंत्रं ॥ २२ ॥

"(18 & 19) Subtract 420 from the Śaka year. The corrections for the planets are as follows :—Moon,—25′ ; Moon's apogee,—114′ ; Moon's node,—96′ ; Jupiter,—47′ ; Venus,—153′ ; Mars,+48′ ; Saturn,+20′ and Mercury, +420′ (20) This, the calculation of planets. . .as suppported by observation. (21) There lived one,. . Sāmba by name, who was revered by all learned men, and from him was born one, known as Trivikrama Bhaṭṭa in the world and who was the "moon for lilies in the eyes of the people". (22) His son Lalla who worshipped the feet of Śiva, the moon-crested Lord and the beloved of Pārvatī complied a 'tantra' equal in merit to the Āryabhaṭa-Siddhānta."

The numbers of revolutions and other elements given in Lalla's works all agree with those of Āryabhaṭa I ; and Lalla has given only the corrections mentioned in the above verses, 18 and 19. From this it is clear that he lived after Āryabhaṭa I. Some evidence is available to determine his date.

The above verse, relating to corrections, has been given in his commentary by Paramādīśvara, the commentator of Āryabhaṭa. There he describes him in the words "tacchiṣyo Lallācāryaḥ", calling Lalla as Āryabhaṭa's disciple. From this and mainly from the method of applying corrections in which 420 has been asked to be subtracted from Śaka, Dr. Kern thinks that the date of Lalla may be Śaka 420 itself. Even the late Janārdana Bālājī Modaka expreses the same view (See Sṛṣṭijñāna monthly, August, 1885, p. 120). There may be many others holding the same view, but they are incorrect. The first reason is that if Lalla had been Āryabhaṭa's disciple and his contemporary, he would not have committed errors in trifling matters which have been pointed out by Bhāskarācārya about Lalla. These errors do not exist in the works of Āryabhaṭa I. The second reason is that if the date of Lalla had been Śaka 420, Brahmagupta would have played seriously in condemning Lalla's works which contain many faults, inasmuch as he (Brahmagupta) has fired volleys of criticism against the works of Āryabhaṭa I even when they do not contain many faults. But the Brahma Siddhānta contains neither Lalla's name nor any of his view. The third reason is that an occasion for applying a correction to a siddhānta does

not arise at the very time of its compilation. Some one suggests a correction to a work only when a perceptible difference in the planets' places, as obtained from the work, comes to notice. Āryabhaṭa compiled his work in Śaka 423, and it is quite impossible that his disciple began to make changes in it from that very date. Had it been the case, Āryabhaṭa himself would have given revolutions (of planets) after taking into consideration this correction. The method of finding Lalla's correcticns requires one only to subtract 420 from the Śaka year ;but it does not mean from this that the corrections were made in that year. The corrections suggested to the Brahma Siddhānta have to be applied from the beginning of Kaliyuga. Similarly, corrections to modern Sūrya Siddhānta are to be applied from the beginning of Kaliyuga. It will, therefore, be ridiculous to say, that becuase of this fact, the corrections came into existence in the beginning of Kaliyuga. The statement that Lalla's corrections were suggested in Śaka 420, is equally ridiculous. One more evidence may be added to this. It is as follows :—

Lalla observes, in the Chapter on "misconceptions"

यदि च भ्रमति क्षमा तदा स्वकुलायं कथमाप्नुयुः खगाः ।। ४२ ।।

"If it be accepted that the earth rotates, then how can the birds flying in the sky, find their own nests ?"

In this, Lalla has criticised those who maintain that the earth rotates. But it is only Āryabhaṭa I who states that the earth rotates. It is, therefore, not probable that his own disciple would hold the opposite view or at any rate criticise him. On the whole, Lalla cannot be the disciple of Āryabhaṭa. Bhāskarācārya's works mention Lalla's name at several places ; but nowhere has he mentioned him as Āryabhaṭa's disciple or even merely as a disciple. Raṅganātha, the commentator of Sūrya Siddhānta, has at one place mentioned "śiṣyādhīvṛddhi-datantra" which simply means' a 'tantra' work which increases the intellectual power of disciples". It is not understood on what basis Paramādīśvara has called Lalla as Āryabhaṭa's disciple. The above verses compiled by Lalla himself show that he has nowhere called himself as Āryabhaṭa's disciple. On the contrary from the words in those verses it appears that he was not Āryabhaṭa's disciple.

From this, Śaka 420 does not seem to be his date. He must have lived many years after Āryabhaṭa.

Lalla has given 359° as the longitude of the junction-star of Revatī. The time for the junction-star of Revatī to cover one degree to the West of the initial point, according to Lalla tantra (that is, from the point occupied by the sun at the moment of the actual Aries Ingress) comes to about Śaka 600. But it has been shown above that Brahmagupta knew nothing about Lalla's work ; Lalla's works describe all instruments except the '*turiya*' (*quadrant*) *instrument* described by Brahmagupta. It shows that Brahmagupta's work was not known to Lalla. This leads one to surmise that both were contemporaries, but residing at distant places.

Śrīpati has compiled his work '*Ratnamālā*' with the help of Lalla's, 'Ratnakośa'. Śrīpati's date is Śaka 961. Lalla must have lived long before this date.

His work does not discuss the question of the precession of equinoxes. This shows that he must have lived about the time of Brahmagupta.

From all these considerations, the author thinks that Lalla's date might be a time near about Śaka 560.

His Ability

It is true that Bhāskarācārya has criticised Lalla, the author of "Dhīvṛd-dhida", but he states in the 20th verse above, that he has determined these corrections already mentioned, after ensuring agreement with the observed positions himself. This shows that he used to take observations himself and was a researcher ; and this fact was very creditable to him. The corrections given to Mercury and other planets show that the need to find them out must have arisen after a period of time had elapsed after Āryabhaṭa. It has already been mentioned that the Karaṇa works 'Karaṇaprakāśa' (Śaka 1014) and 'Bhaṭatulya' (Śaka 1339) were compiled after applying Lalla's corrections to the planets calculated according to the Siddhānta of Āryabhaṭa I.

PADMANĀBHA

Bhāskarācārya refers in his algebra to this name as a writer on algebra Colebrooke* has observed that he appears to have lived before Śrīdhara, as can be seen from Śrīdhara's work described below. Hence Padmanābha's date, as compared with that of Śrīdhara, does not appear to be later than Śaka 700.

Śrīdhara

Mahāvīra's work described below shows that a writer named Śrīdhara lived before him and that he wrote a work on 'vyāktagaṇita' (arithmetic), similar to that of Bhāskarācārya's Līlāvatī. Colebrooke had obtained the book, 'Gaṇiti-asāra', by Śrīdhara. It contained the subjects of arithmetic and mensurationo It shows, that this person Śrīdhara and the one referred to by Mahāvīra in his work, must be the same person, and Śrīdhara's date, as determined from that of Mahāvīra does not appear to be later than Śaka 775. Śrīdhara, mentioned by Bhāskarācārya as the author of algebra, seems to be this very person.

MAHĀVĪRA

He has written 'Sārasaṃgraha' a work on 'vyāktagaṇita' which deals with arithmetic and mensuration. An incomplete copy of the work came to notice in the collection of books belonging to late Dr. Bhau Daji. The description given in its beginning shows that Mahāvīra was a Jain by religion and that he had the patronage of the Jain King Amoghavarṣa. This shows that he lived in the reign of Amoghavarṣa I, the Jain king of the Rāṣṭrakūṭa dynasty, that is, about Śaka 775.

His work 'Sārasaṃgraha' resembles Līlāvatī of Bhāskarācārya but is more extensive and consists of at least 2000 "granths" (or verses in Anuṣṭup metre).

The Sārasaṃgraha contains some lines from Miśrakavyavahāra' (miscellaneous subjects) from the work of Śrīdharācārya, mentioned above.

ĀRYABHAṬA II (ABOUT ŚAKA 875)

His Work

There is another Ārya Siddhānta in addition to the siddhānta of Āryabhaṭa described before. There is a copy of the work, kept in the Deccan College

*Colebrooke's Miscellaneous Essays pp. 442, 450, 470.

Collection, but it is entitled as Laghu-Ārya Siddhānta. But the author himself calls it neither 'bṛhat' (extensive) nor 'laghu' (short). In the very first verse he observes.

विविधखगागमपाटीकुट्टकबीजादिदृष्टशास्त्रेण ॥
आर्यभटेन क्रियते सिद्धांतो रुचिर आर्याभि ॥ १ ॥

"This beautiful Siddhānta has been compiled in the 'Ārya' metre by Āryabhaṭa who has studied various sciences on planetary motions, elementary mathematics, problems in arithmetic, and algebra".

In this, he calls his work a Siddhānta. This author is more modern than the earlier Āryabhaṭa and I have called him as Āryabhaṭa II and his work, Second Ārya Siddhānta, because it is convenient to do so.

His Date

He has not mentioned his date. He has given in his Siddhānta the mean places mentioned by another Siddhānta known as Parāśara Siddhānta. He describes both these siddhāntas,

एतत्सिद्धांतद्वयमीषद्यांते कलौ युगे जातं ॥ २ ॥ अध्याय २,

meaning "compiled when a small part of Kaliyuga had elapsed". In this verse he intends to show to the world that the two Siddhāntas were compiled very soon after the Kaliyuga had started. But I am quite sure that he lived after Brahmagupta, because, even though he maintains that his Siddhānta was compiled very soon after the beginning of Kaliyuga, he includes himself among the authors of "pauruṣa" (human) works. There is no other proof to show that the length of year or other measures adopted by him were in use before Brahmagupta, and all criticisms levelled by the latter against Āryabhaṭa apply to the First Ārya Siddhānta and not at all to this. No subject dealt with in this Siddhānta has been referred to by Brahmagupta. Had this Siddhānta existed in his time, Brahmagupta would not have failed to criticise it in some respect or the other. The Pañcasiddhāntikā does not appear to have mentioned the equinoctial motion. It is not found in the works of Āryabhaṭa I, Brahmagupta or Lalla. But it is given in this Ārya Siddhānta and the authors appear to have attempted to remove the blemishes for which Brahmagupta has criticised Āryabhaṭa I. His work describes the Yuga-system, and the Kalpa begins on Sunday and Brahmagupta has criticised Āryabhaṭa I that his work recommends the planetary calculation, from the beginning of the Yuga when only the 'mean planets' are said to come together and not the 'true planets' (see 46th couplet, Chap. 2). But according to this Āryabhaṭa's work, the true positions of all planets are given to be together at the beginning of Creation. All these facts have convinced the author that he lived after Brahmagupta *i.e.* after Śaka 587. This is the farthest limit of his date. As regards the nearest limit, Bhāskarācārya has quoted him (in his work). In the 65th verse of the chapter on true places, in Siddhānta Śiromaṇi, he observes "Āryabhaṭa and others have mentioned the rising of the 'dṛkkāṇa' *i.e.* the third part of a sign or 10°, to ensure accuracy". Āryabhaṭa I has mentioned the duration of ascendants in terms of arcs of 30° and not of 10° ; but Āryabhaṭa II has mentioned the durations for the ascension of 'dṛkkāṇas' that is arcs of 10° ; in couplets 38 to 40 in the 4th chapter, and such a mention of the duration of 'dṛkkāṇa' is not at present found in any work except in that of Āryabhaṭa II. This shows that Āryabhaṭa referred to by

Bhāskarācārya in the above line is not the first Āryabhaṭa, but the second. from this it is clear that Āryabhaṭa II must have lived before Śaka 1072. He has described the method of calculating ayanāṃśa ; but the equinoctial motion as calculated from it is not found always to be constant, but to increase or decrease much (more discussion about this will be made in the study of the motion of equinoxes). But there is no harm in saying that the equinoctial motion is always constant ; the variation in it is exceedingly small. The modern Sūrya Siddhānta gives a constant motion for it ; but the date of its compilation is not definitely known. The work, Rājamṛgāṅka (Śaka 964) has adopted a constant motion for the equinox for all times. No definite proof of the measures adopted (by) earlier (writers) is at present available. From this, Āryabhaṭa II appears to have lived before the equinoctial motion was correctly known. The Bhaṭotpala's commentary (Śaka 888) quotes from several works, but not from the second Ārya Siddhānta. It shows that even if Āryabhaṭa II lived before Bhaṭotpala, he must have preceded him only by a few years.

The time when the ayanāṃśas, obtained from the Second Ārya Siddhānta, would be equal to the sun's tropical longitude at the true vernal equinox, comes to be about Śaka 900. If he had lived before this year, the date must have been only a few years earlier.

From all these considerations, he seems to have lived about the Śaka 875. It has already been shown before (page 33) that the date of his Siddhānta and that of Parāśara, as found by Bentley, are incorrect.

Description of his Work

His work consists of 18 chapters, which contain 625 couplets. The first 13 chapters deal with all the subjects usually discussed in different chapters in karaṇa works. The 14th chapter deals with the celestial sphere and problems concerning it. The 15th chapter consisting of 120 couplets is devoted to Pāṭīgaṇita (i.e. arithmetic and mensuration) ; and it contains almost all the questions dealt with in Bhāskarācārya's Līlāvatī. The 16th chapter is devoted to bhuvanakośa (Universe) i.e. the description of the three worlds. The 17th Chapter gives a theory of the mean motions of Planets, and the 18th chapter deals with algebra, and particulary the 'kuttaka' problems in it. It gives some special information not given by Brahmagupta.

Numerical Code

He has adopted the usual conventional code to denote numbers in 'Pāṭīgaṇita' (i.e. arithmetic and mensuration) only ; otherwise he has used, everywhere else, the letters of the alphabet to denote numbers. These letter values are different from those used by Āryabhaṭa I. They are :—

Consonants	Numbers denoted	Consonants	Numbers denoted
Ka, ṭa, pa, ya . .	1	ca, ta, ṣa . . .	6
kha, ṭha, pha, ra, . .	2	cha, tha, sa . . .	7
ga, ḍa, ba, la,. . .	3	ja, da, ha, . . .	8
gha, ḍha, bha, ba, . .	4	jha, dha, . . .	9
ṅa, ṇa, ma, śa . .	5	ña, na, . . .	0

While denoting numbers by letters, Āryabhaṭa I has not abandoned the general rule that', "digits are written from right to left" but this Āryabhaṭa has differed from it, and has adopted the system of writing the digits from left to right. Example : According to this system the word 'ghaḍapha' denotes 432.

It has been pointed out in the account of Āryabhaṭa I how confusion is caused by adopting his system of code letters. The same remark applies to this Āryabhaṭa also.

Below are given the numbers of revolutions and other elements etc. in one Kalpa as given by his Siddhhānta as well as by that of Parāśara.

	Second Ārya Siddhānta	Parāśara Siddhānta
Years spent over creation	3024000 In one Kalpa	0 In one Kalpa
Revol. of stars	1582237542000	1582237570000
Revol. of Sun	4320000000	4320000000
Sāvana days	1577917542000	1577917570000
Moon's revolutions	57753334000	57753334515
Moon's apogee : revolutions	488108674	488104634
Moon's node : revolutions	232313354	232313235
Mars	2296831000	2296833037
Mercury	17937054671	17937055474
Jupiter	364221682	364219955
Venus	7022371432	7022372148
Saturn	146569000	146571813
Solar months	51840000000	51840000000
Intercalary months	1593334000	1593334515
Lunar months	53433334000	53433334515
Tithis	1603000020000	1603000035450
Suppressed days	25082478000	25082465450

Planets	Revolutions of apsides in a Kalpa		Revolutions of nodes in a Kalpa	
	Second Ārya Siddhānta	Parāśara Siddhānta	Second Ārya Siddhānta	Parāśara Siddhānta
Sun . . .	461	480		
Mars . . .	299	327	298	245
Mercury . .	339	356	524	648
Jupiter . . .	830	982	96	190
Venus . . .	654	526	947	893
Saturn . . .	76	54	620	630

Length of year, according to Ārya Siddhānta.—365^{d}—15^{gh}—31^{pal}—17^{vip}—6^{pvp}
Length of year, according to ParāŚara Śiddhānta—365—15—31—18—30.

According to Ārya Siddhānta it is assumed that some years have been spent over creation. No such assumption has been made in ParāŚara Siddhānta. According to both the Siddhāntas the planets appear to come together not in the beginning of Kaliyuga, but at the beginning of Creation. The length of the year according to both is nearly equal to that of the rectified Brahma Siddhānta. This Āryabhaṭa has mentioned the number of revolutions of the "saptarṣi" stars (Great Bear), on the assumption that they have some motion. But as a matter of fact the Saptarṣis have, practically, no motion.

Parāśara Siddhānta

He remarks about Parāśara as follows :—

पाराशर्या दिविचरयोगे नैच्छंति दृष्टिफलं ।। १ ।।

अध्याय ११

"The followers of Parāśara Siddhānta do not accept any 'phala' *i.e.*, result for the mutual aspects of planets";

and after passing the remark,

कलिसंज्ञे युगपादे पाराशर्यं मतं प्रशस्तमतः ।। वक्ष्ये तदहं...... ।। १ ।।

अध्याय २

meaning "I describe here Parāśara's view since it is the best in Kaliyuga", he has mentioned its elements. From this, the Parāśara Siddhānta appears to be an independant work; but it is not available at present.

BALABHADRA

The commentary on Brahma Siddhānta by Pṛthūdaka, cites Balabhadra's name several times and has given a number of verses in "anuṣṭup" metre in his name. Those verses quote, in versified form, the elements given in the Brahma-Siddhānta itself. Even Bhaṭotpala's commentary on the Bṛhat Saṃhitā quotes some verses and Ārya couplets in the name of Balabhadra. They relate to the section on mathematics ; they have, however, no connection with the Brahma Siddhānta. This shows that he may have compiled an independent work on planetary calculation. The lines which have been given by Pṛthūdaka as quoted from Balabhadra may have been from his commentary on the Brahma Siddhānta. The author thinks that it might have been customary in ancient days to have at least a part of the commentary in verse form, when the text itself was in verse form. That Paramādīśara has quoted in his commentary on Āryabhaṭīya, some verses from his commentary on Līlāvatī would serve as an instance in point. In case Balabhadra had written an independent work, it is not now available. His date is clearly earlier than that of Bhaṭotpala, that is Śaka 888.

BHAṬOTPALA

His Date

He was a great commentator. He has stated the date of the compilation of his commentary on Bṛhajjātaka in these lines.

चैत्रमासस्य पंचम्यां सितायां गुरुवासरे ।। वस्वष्टाष्ट ८८८ मिते शाके कृतेयं विवृतिर्मया ।।

meaning, "I wrote this commentary on Thursday, the 5th lunar day of the bright half of Caitra in Śaka 888", and that of the commentary on Bṛhatsaṃhitā in the verse.

फाल्गुनस्य द्वितीयायामसितायां गुरोर्दिने ।। वस्वष्टाष्ट ८८८ मित शाके कृतेयं विवृतिर्मया ।।

meaning "I wrote this commentary on Thursday, the 2nd lunar day of the dark half of Phālguna in Śaka 888."

If Śaka 888 be regarded as an 'elapsed' year, the second lunar day of the dark half of either amānta Māgha or Phālguna is not found to fall on Thursday. The 2nd lunar day of the bright half of Phālguna was a Thursday. A Thursday is found to fall on the 2nd lunar day of the dark half of (Amānta) Māgha in Śaka 887, but not on the 2nd lunar day of either the bright or dark half of Phālguna. This shows that the Śaka year 888 referred to in the second verse must be the "current" year, equivalent to Śaka 887 elapsed ; and the Phālguna may be the month belonging to the 'pūrṇimānta' system ; that is, it must be the amānta Māgha.

But the 5th lunar day of the bright half of Caitra does not fall on Thursday either in Śaka 888 or in 887. In Śaka 887, lhe day happens to be Friday and in Śaka 888, it was a Wednesday. It appears that there must be some error in this ; and so long as it is not detected, the Śaka 888 mentioned in the verse cannot definitely be said tc be a 'current' year. In any case, there is no dcubt that the year must be one of the two Śakas, 888 or 887.

Commentaries

Utpala has written a commentary on Khaṇḍakhādya, but its Śaka is not known. However, in the commentary on the 5th chapter of Bṛhatsaṃhitā, one

comes across the remark "khaṇḍakhādyakaraṇe asmadīya vacanaṃ", meaning "as I have stated in the commentary on Khaṇḍakhādya". It, therefore, shows that he wrote the commentary on Khaṇḍakhādya before this. Similarly, a reference made by him in his commentary, on Bṛhatsaṃhitā (Chap. 44) shows that his commentary on Varāha's travel was written before that on Bṛhatsaṃhitā. He has written a commentary on Laghujātaka also. He has, thus written commentaries on the following works compiled by Varāha—Yātrā, Bṛhajjātaka, Laghujātaka, and Bṛhatsaṃhitā, and a commentary on Brahmagupta's Khaṇḍa-Khādya. The commentary on 'yātrā' (travel) is not now available. Those on Bṛhajjātaka, Laghujātaka and Bṛhatsaṃhitā are available in this province, and of them, the first two have been printed.

Place

The commentary on Khaṇḍakhādya, written on the bark of the birch tree which is now in the Deccan College Collection, was originally found in Kashmi. The author does not think this commentary is available in other provinces That this commentary was well known in Kashmir can be seen from another commentary on Khaṇḍakhādya written in Śaka 1564 and from the Pañcāṅga Kautuka written in Śaka 1567, both written in Kashmir. It shows that Bhaṭotpala was a resident of Kashmir ; and Varuṇa, the commentator of Khaṇḍakhādya, clearly states that he was a resident of Kashmir

Independent Works

He seems to have compiled an independent work on the mathematical branch as can be seen from a couplet given by him at a place with the remark "as I have stated" in the first chapter of the commentary on the Bṛhatsaṃhitā. He might have taken the quotation from his commentary on Khaṇḍakhādya. Bhaṭotpala has compiled 'praśnajñyāna' a work on 'praśna' (Questions), consisting of 72 āryā couplets.

Love of Research

It appears from the commentary on the Bṛhatsaṃhitā that Utpala was a keen researcher of ancient works and his reading was vast. He has written at several places that Varāhamihira had taken the help of ancient works on most of the questions on which he had written, and he (Utpala) has even cited the names of those works at some places. Utpala has also given quotations from the authors of ancient Saṃhitā works on those subjects at all or almost all such places. At some places are found quotations from as many as 8 to 10 authors of Saṃhita works. It is clear that all these saṃhitās were aviailable in his time. Similarly, he has given the quotations and names of several 'pauruṣa' (human) writers of works on Saṃhitā, Jātaka or some of the subsections of the subjects. Utpala's commentary on the Bṛhatsaṃhitā would be of great help in assessing the state of the knowledge of various subjects relating to the saṃhitā branch, and its growth in our country, and because of this and other reasons, the commentarly is worth publishing. The commentary is very extensive. The whole volume may be found to consist of about 14000* "granths" verses and (the above two verses show that) this voluminous commentary was compiled by him in about eleven month's time, which is indeed a very remarkable feat. Utpala has written a commentary on 'ṣatūpañcāśikā, a work on Jātaka by Pṛthuyaśa, son of Varāhamihira'a copy of which is kept in the Poona College Collection (No. 355 of 1882-83).

* The term "Gramtha" in such context means verses in Anuṣṭup metre Consisting of 32 letters each.

CATURVEDA PṚTHŪDAKA SWĀMĪ

Date

He has written a commentary on Brahmagupta's Brahma Siddhānta. Bhāskarācārya has cited his name several times. Pṛthūdaka's name also appears in the commentary on Khaṇḍakhādya by Varuṇa, which was written about Śaka 962. This indicates that he lived before Śaka 962. It seems that he was not known to Bhaṭotpala. But his commentary on Brahma Siddhānta cites Balabhadra's name. From this he appears to have been Bhaṭotpala's contemporary or he may have belonged to a slightly later date. In other words, date comes to about Śaka 900.

Place

He has remarked in the 35th couplet of the 7th chapter of Brahma Siddhānta as follows :—

Atha sākṣabhāgāḥ kānyakubje......kānyakubje swanatabhāgā "meaning degrees of latitude in Kānyakubja......degrees of zenith distance in Kānya kubja". He has similarly remarked in the 8th couplet "yatheha Kānyakubje' meaning "as it is in Kānyakubja". These remarks show that he either belonged to the kānyakubja area or may even have been a resident of Kanauj.

His Works

He has written a commentary on the first 10 chapters of the Brahma Siddhānta, a copy of which is in the Poona College Collection. He has, at many places in the commentary, remarked "this has already been stated by me in the chapter on the celestial sphere". It seems that he first wrote his commentary on Golādhyāya, the 21st chapter of Brahma Siddhānta, and then on the first ten chapters of the work. One of the last sentences in his commentary on the ten chapters shows that his commentary on Golādhyāya contains about 1500 verses. The commentary on the ten chapters contains about 5300 verses. The commentary is, on the whole, a good one. When the original work itself is good, it is no wonder that the commentary on it is also faultless. However, Bhāskarācārya has criticised him at one or two places to the effect that "Caturveda has spoiled (or misconstrued) the sense of the original composition of Brahmagupta which was really beautiful", and this charge is justified. This commentator seems to be a plain speaker. At one place he has criticised Brahmagupta with the remark "It is nothing but needless repetition" (see 28th and 29th couplet, from chap. 7). He has written at the end of the tenth chapter, "Pṛthuswāmī, the Caturveda, who is the son of Madhu, has compiled this", and at the end of some chapters he has spoken of himself as "son of Madhusūdan'a". From this, his father's name appears to be Madhusūdana.

The commentary by Varuṇa shows that Pṛthūdaka may have written a commentary on the Khaṇḍakhādya also and part of it was in verse form. He calls himself Pṛthuswāmī. One wonders whether this means that he had entered upon the fourth stage of life (that of Sannyāsī) when he wrote the commentary. His commentary on Brahma Siddhānta does not contain quotations from any 'pauruṣa' writers except those of Balabhadra. Those from "apauruṣeya" (divine) writers, also are very few. The only names which have occurred in his works are, "Bhagavān Manu, Vyāsa Muni and the author of Purāṇas".

ŚRĪPATI

His Works

He has the *Siddhāntaśekhara* and the *Dhīkoṭidakaraṇa*, two astronomical works to his credit. He also wrote Ratnamālā, a work on Muhūrta and Jātakapaddhati, one on astrology. The author has not seen his work *Siddhāntaśekhara*. The name of this work could not be found even in the catalogues of libraries like the Government Collection of the Deccan College, and the Ānandāśrama Collection of Poona. But Bhāskarācārya has referred to his work. Similarly, the Muhūrta work, Jyotiṣadarpaṇa and the Marīci commentary on Siddhānta Śiromaṇi have quoted him. The work Dhikoṭidakaraṇa is not at all known now ; but the author found in Ānandāśrama, Poona, a chapter on the eclipses of the sun and the moon from it. It consists of 19 verses only.

Date

No books printed so far give any clue to his date ; but I found Śrīpati's date in the small and incomplete copy of the Karaṇa mentioned above. The Karaṇa has adopted Śaka 961 as the epoch which shows that Śrīpati lived about that year.

His Commentaries

There is a brief commentary on the two chapters mentioned above. It contains two solved examples on eclipses for which the Śaka years 1532 and 1593 have been adopted. It shows that the Karaṇa work appears to have been in use up to that year in some regions. Both works, Ratnamālā and Jātakapaddhati have been printed at Vārānasī and both have a commentary on them, entitled Mahādeva.

His Lineage

Śrīpati has mentioned nothing about his place, family etc. However, Mahādeva, in the beginning of his commentary on Ratnamālā observes :

कश्यपवंशपुंडरीकखंडमार्तंडः केशवस्य पौत्रःनागदेवस्य सूनुःश्रीपतिःसंहितार्थं अभिधातुमिच्छुःआह.

Translation.—Śrīpati, son of Nāgadeva and grandson of Keśava, and who was like the Sun giving delight to lotuses in the form of descendants of Kaśyapa with the desire of explaining the meaning of the saṃhitā, observes :—......

From this his 'gotra' seems to be Kaśyapa, Nāgadeva the name of his father and Keśava, that of his grandfather.

His School

Śrīpati says that he wrote his work Ratnamālā on the basis of Lalla's Ratnakośa. Even the work Dhīkoṭidakaraṇa shows that he was the followed of Lalla, that is that of Āryapakṣa.

VARUṆA

Date and Residence

He has written a commentary on Brahmagupta's Khaṇḍakhādya. It has adopted chiefly Śaka 962 for solving examples, and this shows his date to be

about the same year. The commentary shows him to be a resident of a village named something like 'Cārayyāt' in the area 'Uruṣā' region, near Kashmir. The position of the place has been mentioned by him as latitude 34°22′ and longitude equal to 99 yojanas, east of Ujjayinī meridian (*i.e.* about 7½° or 450 miles).

A surprising fact has been noticed in his commentary on Khaṇḍakhādya. At the very outset it has been remarked, in his commentary on the calculation of ahargaṇa ;

उक्तंच सिद्धांतशिरोमणौ । अभीष्टवारार्थमहर्गणश्चैत् सैको निरेकस्तिथयोपि तद्वत् ।।
तदाधिमासावमशेषके च कल्पाधिमासावमयुक्तहीने ।।*

Translation.—"So is said in the Siddhāntaśiromaṇi. If you are calculating ahargaṇa corresponding to a particular day of the week, you will have either to add 1 to or subtract 1 from the result. The same will have to be done in the case of particular tithis. Similarly while finding the 'adhimāsa śeṣa ' or 'avama śeṣa' the number of intercalary and 'avama' days in a Kalpa undergoes a similar positive or negative change".

This verse is given by Bhāskarācārya in his Siddhāntaśiromaṇī and on the basis of this (verse) Varuṇa should be said to have lived after Śaka 1072 ; but several examples in his commentary show that his date comes to about Śaka 962 and there is absolutely no doubt about it. This verse clearly appears to have been interpolated by some one later on ; otherwise, who knows if there existed another work, named Siddhāntaśiromaṇi, compiled earlier than Śaka 962, which contained this verse word for word?

RĀJAMṚGĀṄKA

Date

This is a karaṇa work. It has adopted Śaka 964 as its epoch. The epochal positions have been given for the Sunrise (mean sunrise) i.e. for Sunday morning, the 13th cum 14th lunar day of the dark half of amānta Phālguna of Śaka 963.

Basis

That the work has been compiled after applying corrections to the planetary positions derived from the Brahma Siddhānta has nowhere been explicitly stated ; still, the epochal positions are found to agree with calculated figures when the corrections are applied to the planets according to the Brahma Siddhānta. The epochal positions are as follows :—

	S	°	′	″		S	°	′	″
Sun	10	28	45	0	Venus	6	7	52	39
Moon	10	9	2	53	Saturn	6	20	4	31
Mars	8	2	9	47	Moon's apogee	5	10	30	45
Mercury	8	1	33	15	Moon's node	2	16	58	5
Jupiter	3	1	0	30					

*There are two Versions of the book in the Deccan College Collection under Nos. 526 and 527 of 1875—76 A.D. This verse has been taken from the first of them.

The positions of apsides and nodes at the epoch of the Karaṇa work have also been taken from the Brahma Siddhānta. The correction suggested in it and the method of finding it is given in the following verse :—

नंदाद्रींद्वग्नि ३१७६ संयुक्तान् भजेत् खाभ्राभ्रभानु १२००० भिः ।।
शाकाब्दानविनष्टं तु भाजकाच्छेषमुत्सृजेत ।। १७ ।।
तयोरल्पं द्विशत्या २०० तं बीजं लिप्तादिकं पृथक् ।।
त्रिभिः ३ शरै ५ र्भुवा १ द्व्यक्षै ५२ र्बाणै ५ स्तिथिभि १५ रब्धिभिः ४ ।। १८ ।।
द्विकेन २ यमले २ नैवं गुण्यमर्कादिषु क्रमात् ।। स्वं ज्ञशीघ्रे धरासूनौ सूर्यपुत्रेपरेष्वृणं ।। १६ ।
मध्यमाधिकार

Translation.—Add 3179 to the Śaka year. Divide the sum by 12000. Subtract the remainder from the divisor itself (*i.e.* from 12000). Divide the smaller of the two (*viz* the remainder or 12000-remainder) by 200, and multiply it by 3,5,1,52,5,15,4,2 & 2, respectively in the case of the planets in order (*viz.* the Sun, the Moon, Mars, Mercury, Jupiter, Venus, Saturn, Moon's apogee, and Moon's node) so as to obtain the respective corrections. They are positive for Mercury, Mars and Saturn, and negative for others.

Author

—Chapter on mean places. The Colophon contains the following line :

इत्युर्वीपतिवृंदवंदितपदद्वंद्वेन सद्बुद्धिना ।। श्रीभोजेन कृतं मृगांककरणं ज्योतिर्विदां प्रीतये ।।

Translation :—"This Karaṇa work, known as 'Mṛgāṅka', has been compiled with the good intention of satisfying the astronomers, by Śri Bhoja who is revered by rulers of the earth".

This shows that this Karaṇa was compiled by King Bhoja. The above-mentioned correction is not found in any of the earlier works now availablle. It appears to have been devised at the time of Bhoja himself. It seems probable that he patronised some astronomers, got them to take observations for a number of years, and after comparing the observed places with those calculated from the Brahma Siddhānta, he finally determined the figures for correction so as to agree with other works also. It is not known if King Bhoja possessed the knowledge of astronomy as would be sufficient to compile a Karaṇa work himself. If not, the astronomers under his patronage may have compiled it and named it after him. But even if that be the case, there is no doubt that the astronomers had acquired the ability to compile a new work in the light of observations only on account of the royal patronage.

Subject Matter

This work contains only two chapters viz. one chapter on mean places and other on true places of planets and the two together contain 69 verses. It appears that they may be calculating eclipses directly with the help of the Siddhāntas. This work is not in use anywhere at present ; and because of the lapse of many years, the ahargaṇa calculated from it would be a very large number and hence very inconvenient for calculating the mean places ; because of this and also other Karaṇa works which have been compiled later, this work may naturally have gone out of use. Even then it appears to have been in use for a

considerable number of years. Mahādevī Sāraṇia, Karaṇa work following the Brahmapakṣa was compiled in Śaka 1238. It refers Rājamṛgāṅka. Similarly, Tājakasāra, a work compiled in Śaka 1445 contains the line,

श्रीसूर्यतुल्यात्करणोत्तमाद्वा स्पष्टा ग्रहा राजमृगांकतो वा ।।

which means, "true places can be obtained from Śrīsūryatulya, Karaṇottama or Rājamṛgāṅka, from which it appears that the true places of planets used to be calculated from the Rājamṛgāṅka."

The method of finding ayanāṃśa has been described in this work in the line.

शक: पंचाब्धिवेदो ४४५ न: षष्टि ६० भक्तोयनांशका: ।। २५ ।।

मध्यमाधिकार

Translation.—The difference between the Śaka year and 445, when multiplied by 60 gives the ayanāṃśas.

KARAṆA KAMALA MĀRTAṆḌA

This is a Karaṇa work. Its epochal year is Śaka 980. The author of this work also is, like that of Rājamṛgāṅka, a king. The following verses are written at the end of the work :

बलभान्वयसंजातो विरोचनसुत: सुधी: ।। इंद दशबल: श्रीमान् चक्रे करणमुत्तमम् ।। १० ।।

धन्यैरार्यभटादिभिर्निजगुणैर्दिंडीरफेलोज्वलैराब्रह्यांडविसारिभि: प्रतिदिनं विस्तारिता: कीर्तय: ।।

स्मृत्वा तच्चरणांबुजानि रचितोऽस्माभि: परप्रार्थितैर्ग्रंथोयं तदुपार्जितैश्च सुकृतै: प्रीतिं भजंतां प्रजा: ।। ११ ।।

अधि १०

Translation :—"(10) This "best of the Karaṇa works" has been compiled by the learned king Daśabala, son of Virocana, and belonging to Valabha dynasty.

(11) Illustrious scholars like Āryabhaṭa and others have spread their fame every day by power of their accomplishments, spotless like foam and well-known throughout the world.

At the request of others this work has been compiled by me, offering homage at their sacred feet. May people be happy with the benefits acquired by its help."

His School

It appears that the work was compiled by king Daśabala of the Valabha dynasty. It does not state the name of the Siddhānta followed; still, the annual motions given for its 'abdapa' (moment of the mean Aries Ingress) and tithi-śuddhi (means tithi elapsed at the mean Aries Ingress) agree with the figures calculated from the Brahma Siddhānta as corrected with the help of Rājamṛgāṅka. Similarly, the sides, the 'nakṣatra' dhruvas, nodes, etc. agree with the Brahma Siddhānta. From this, it is undoubtedly proved that the work conforms to the corrected Brahma Siddhānta. It has not separately mentioned the corrections; the motions have been determined after actually taking these into account.

Advantages

The mean planetary places used to be calculated from the ahargaṇa in well-known earlier Karaṇa works like the Pañca Siddhāntikā, Khaṇḍakhādya and Rājamṛgāṅka. In other words, they describe the method of calculating mean motions and mean places of planets from the number of days obtained by multiplying by 365¼ the number of years elapsed after (epoch of) the Karaṇa work. But the ahargaṇa increases with the increase in the number of years elapsed, and this causes lengthy multiplications and divisions. If tables showing mean motions for successive periods of days are prepared for calculating mean places, the calculation of mean places of planets would take very little time, or if mean places are found from the number of years elapsed after the epochal year, on the basis of the yearly mean motions of planets, even then it would take very little time. But it is surprising that the Pañcasiddhāntikā, Khaṇḍakhādya and Rājamṛgāṅka, and even well known Karaṇa works like the Karaṇa prakāśa, Karaṇakutūhala and Grahalāghava which were compiled after them, and from which calculations are made even now, give the extremely laborious method of finding mean places of planets from the total ahargaṇa. The mean place of a planet can be obtained from 'varṣagaṇa' or from tables in one tenth of time or even less required for finding the place by that method. The present work, Karaṇa Kamala Mārtaṇḍa, has not only given methods for finding planets' places from 'varṣagaṇa' but has also prepared tables of motions in period of years in order to save the labours of multiplying the 'varṣagaṇa' by the figures of annual motions. This is a great advantage. Some astronomers, who following the Grahalāghava, are, in these days, found using tables giving motions for days which are useful in finding planets positions from the ahargaṇa. Similar tables based on the Pañca Siddhāntikā and other works, might have been compiled by astronomers at different times ;but many ignorant astronomers are found who prefer the overlaborious method given in the old works instead of making use of tables, because these are not met with in the works. The author of Karaṇa-Kamala Mārtaṇḍa deserves praise in this respect. The work gives the calculation of mean places of planets from the mean Aries Ingress. It is somewhat surprising that the positions at the epoch and the yearly motions are not given in verse form; but it seems that these may have been given in the tables which accompany the work. The work seen by the author (Deccan College Collection No. 20 of 1870-71) however, contains tables for 'Tithi Śuddhi' only. The work, as it stands, is not sufficiently useful for making planetary calculation. It contains the following ten chapters consisting of 279 verses in 'anuṣṭup' metre:- mean places (of planets); three problems; lunar eclipse; solar eclipse; risings and settings; elevations of the moon's cusps; soli-lunar parallels of declinations; conjunctions of planets; true intercalary months; and calculation of the saṃvatsara (year). This work has assumed Śaka year 444 as the no-precession year and one minute of arc as the annual rate of precession.

The Aufrecht catalogue mentions another work by Daśabala, entitled *Cintāmaṇi Sāraṇikā* which contains tables useful for almanac-making. Daśabala claims that the work of almanac-making can be expedited to a great extent through the aid of his work. He also appears to claim that the like of his work was never compiled before

KARAṆA PRAKĀŚA

Date and Author

This is a Karaṇa work. The epoch of the work is Śaka 1014. The author, observes, in the beginning,

नत्वाहमार्यभटशास्त्रसमं करोमि श्रीब्रह्मदेवगणकः करणप्रकाशं ।।

Translation :—"I, the astronomer, Brahmadeva by name, most humbly compile this work, Karaṇa Prakāśa, in conformity with the 'Science' of Āryabhaṭa".

From this it is clear that, the astronomer, Brahmadeva, compiled this work following the (principles of) Āryabhaṭīya. The colophon of the work is as follows

आसीत्पार्थिववृंदवंदितपदांभोजद्वयो माथुराः
श्रीश्रीश्चंद्रबुधे गुणैकवसतिः ख्यातो द्विजेंद्रः क्षितौ ।।
नत्वा तस्य सुतोंघ्रिपंकजयुगं खंडेंदुचूडामणेः
वृत्तैः स्पष्टमिदं चकार करणं श्रीब्रह्लदेवः सुधीः ।। ११ ।।

Translation :—"There lived a great Brāhmaṇa scholar, named Śrī Candra who was a (?) Māthura, reputed all over the world, who was the abode of virtues and whose feet were worshipped by a number of kings. His intelligent son, Brahmadeva, after worshipping the feet of Lord Śhiva, compiled this very accurate Karaṇa work in metrical form."

It appears from this that Candra was the name of Brahmadeva's father. Candra may have received the patronage of some king, or else as the above verse indicates, he m ust have been at least highly respected by some king. The name 'Māthura,' suggests that he may have been a resident of Māthura.

School

It is said in the beginning that this work was intended to be in conformity with the science of Āryabhaṭa and it is the first Āryabhaṭa who is thus referred to. Even then, the positions and motions of planets given in it agree with those obtained from the First Ārya Siddhānta only after Lalla's corrections are applied to the latter. This does not mention the corrections separately. The planetary positions and motions have been determined after taking into consideration those corrections. The epochal positions mentioned in it are true for the mean sunrise of Friday, the 1st lunar day of the bright half of Caitra of Śaka 1014.

They are :—

	s	°	′	″		s	°	′	″
Sun	11	16	32	57	Venus	10	11	28	58
Moon	11	27	20	20	Saturn	3	2	14	23
Mars	3	13	20	6	Moon's Apogee	1	5	49	16
Mercury	7	4	31	12	Moon's node	1	3	17	12
Jupiter	6	2	56	27					

These positions are found to agree, even to the seconds, with those obtained from the First Āryabhaṭīya after Lalla's corrections are applied to the latter.

Contents

The work describes the method of caculating the mean places (of planets) from the ahargaṇa. It contains the following 9 chapters, viz. (i) mean places (ii) true places (iii) Geocentric calculation of the five planets (iv) Shadow (v) Lunar eclipse (vi) Solar eclipse (vii) Risings and settings (of planets) (viii) Elevation of the moon's cusps (ix) conjunctions of planets. This work has assumed Śaka 445 as the zero-precession year, and 1′ as the rate of annual precession.

Its Use

There are two kinds of Ekādaśī fast Smārta and Bhāgavata. If on the day, preceding the Ekādaśī day, the tenth tithi (Daśamī) lasts for 56 ghaṭis or more (after sunrise), the followers of 'Bhāgavata' School do not observe the fast on that day, as it is regarded as "daśami-viddha" (*i.e.* associated with the 10th tithi), but observe it on the next day. In finding the duration of the 10th tithi in ghaṭis, the followers of the Vaiṣṇava sect in Sholapur, Karnatak and major part of the Deccan, follow the Āryapakṣa. The work, Karaṇa Prakāśa, follows the Āryapakṣa, and any tithi calculated by it happens to be longer than that calculated by the Sūrya Siddhānta or Brahma Siddhānta, by about 2 or 3 ghaṭis. The author does not think that an almanac giving all tithis as calculated from the Karaṇaprakāśa is any where in use at present ; because in order to prepare Grahalāghava almanacs, tables which are given in Tithi Cintāmaṇi are available, and the calculations are made very quickly with their help ; there are no similar means for making calculations according to Karaṇaprakāśa. For this reason, the followers of Vaiṣṇava sect, especially in Mahārāṣṭra, use the Grahalāghava almanacs for other tithis, but adopt the Āryapakṣa in the case of Ekādaśī only. And this too is done only approximately on the assumption that the Āryapakṣa's tithi is always longer than that of Grahalāghava pakṣa by about two ghaṭis. Hence, if the almanac according to Grahalāghava shows the duration of the 10th tithi as 54 ghaṭis, the next tithi, viz. the 11th tithi, is regarded as 'daśami-viddha,' as its duration is bound to be 56 ghaṭis according to Āryapakṣa. The Grahalāghava almanac for Śaka 1809 gives 52^{g} —15^{p} , as the duration of the 10th tithi on Friday, in the dark half of Āṣāḍha, 54^{g} —32^{p} as that of the 11th tithi on Saturday, and 55^{g}—39^{p} as that of the 12th tithi on Sunday*. According to this calculation, the Ekādaśī is not "daśamīviddha", nor is there any other reason for recommending two days for observing Ekādaśī ; and hence, all Marāṭhī almanacs have shown Ekādaśī as falling on Saturday. But the author had a chance to meet a Vaiṣṇava Ācārya of Raichur side, along with a party of his disciples. He told the author that they were going to observe the Ekādaśī on the second day, and on being asked the reason why, he uttered some words like Āryapakṣa, Karaṇaprakāśa, liptā etc. but he did not understand what Āryapakṣa and Karaṇaprakāśa meant. And after a few searching questions he admitted that they were going to observe the Ekādaśī on the next day, because they had received such instructions from Dharwar. The author does not think that any one even in those parts actually calculates tithis from Karaṇaprakāśa. He has also seen a manuscript almanac of Śaka 1758 compiled at Bijapur. It also appears to have been calculated with the help of Grahalāghava or similar other works. It had, however, shown separately the 10th and 11th tithis calculated from Karaṇaprakāśa. The author once met a Vaiṣṇava astronomer from Sholapur who told him that they used to calculate the duration of Ekādaśī only sometimes from Karaṇaprakāśa. A learned astronomer from Bid once

*These figures have been copied from the Grahalāghava almanac published in the Sāyana Pañcāṅga of Śaka 1809.

met him in Śaka 1806. He knew the complete method of calculatior based on Karaṇaprakāśa but he told the author that they did not always make their calculations from Karaṇaprakāśa. I actually did the calculatiors for the 'daśamī' referred to above, from Karaṇaprakāśa and obtained its duration ss 54ʰ—59ᵖ after mean sunrise and 56 ghaṭis after true sunrise, for the longitude of Ujjayinī*. In short, the Karaṇaprakāśa is still in use to a certain extent. The author had to take a lot of trouble in procuring a copy of the work, and get one.

The Three Schools

It must be mentioned here that the tithi, according to Āryapakṣa, is found to be longer by 2 or 3 ghaṭis, only if Lalla's correction is applied to the calculations made from First Ārya Siddhānta otherwise not. Hence, it appears that a different criterion governing the observance of Ekādaśī, according to Ārya-pakṣa, might have been introduced, sometime after Lalla, for such criterion could not have existed before. There is a work on 'Muhūrta' (compiled in Śaka 1493) known as Muhūrta Mārtaṇḍa, which states that the tithi according to Āryapakṣa is longer than that according to Brahmapakṣa, by about four ghaṭis. This work and the Grahalāghava show that, in the 15th Centuıy of Śaka era, the differences of the three schools (Ārya, Brahma and Saura) had become acute and each had its own circle of followers. Karaṇa Kutuhala and Rājamṛgāṅka are works following the Brahmapakṣa. Khaṇḍakhādya can be said to belong to the Saurapakṣa. No independent work compiled prior to Śaka 1014 following the Āryapakṣa, is available. Hence, the three schools appear to have become clearly divergent from Śaka 1000 or perhaps even from Lalla's time, and their followers might have begun to take pride in their respective creed.

The positions of planets mentioned in Grahalāghava as belonging to Ārya-pakṣa have been calculated from the Karaṇaprakāśa.

BHĀSVATĪ KARAṆA

Date, Author and place

This is a Karaṇa work. It has adopted Śaka 1021 as the epochal year. It has been compiled by an astronomer named Śatānanda. Aniruddha, the commentator of Bhāsvatī Karaṇa, says that Śatānanda was a resident of Puruśottamapurī that is Jagannāthapurī, and that the epochal positions given by him are true for that place. The convention generally followed is that the epochal positions are given as for Ujjayinī, irrespective of the place where the siddhānta works are compiled. But the author of Bhāsvatīkaraṇa appears to have departed from the convention, since Jagannāthapurī happens to be far away from the meridian of Ujjayinī and he was right. Śatānanda has, in the beginning, observed, "natvā Murāreścarṇāravindam" meaning, "after saluting

*Even four hour's labour will not be sufficient to calculate figures for Ekdāaśī with the help of Karaṇaprakāśa. The author has done the calculation in about three quarters of an hour by another method which is easier than that and still gives results in conformity with the Karaṇaprakāśa.

the feet of Murārī (Lord Kṛṣṇa). From this, Mādhava, one of his commentators, says that he was a Vaiṣṇava. "Śatānanda observes in the first Adhikāra-

अथ प्रवक्ष्ये मिहिरोपदेशात् तत्सूर्यसिद्धांतसमं समासात् ॥ ३ ॥

Translation.—"Now by favour of God Mihira, I compile a brief work equal to the Sūrya Siddhānta in merit".

Basis

Mādhava, one of the commentators of his Bhāsvatīkaraṇa interprets the word "Mihira' as the sun, and interprets the words "like his Siddhānta" as "from the Sūrya Siddhānta", and he has attempted to explain the positions and motions of planets in it with the help of the modern Sūrya Siddhānta, but he has failed in this attempt. He is everywhere required to justify his stand by remarking that "the Ācarya has ignored the slight differences." Mādhava has not at all understood the fact that Śatānanda compiled this Karaṇa work with the help of the Sūrya Siddhānta of Varāha's Pañca Siddhāntikā. The Pañca Siddhāntikā appears to have gone quite out of vogue in his time (Śaka 1442) and this may have been the reason for misunderstanding. The author has seen many other commentaries on Bhāsvatī but they do not explain the basis of the 'Kṣepaka'.

The epochal positions given by the Bhāsvatī are those, true for the moment of true Aries Ingress of Thursday, the New Moon day of the 'amānta' Caitra of Śaka 1021. The author could not exactly find for what moment on that day they are true, and hence, he could not verify if they agree upto minutes and seconds of longitude. However, the epochal positions are definitely true for the day of the true Aries Ingress and they agree,* for the most part with the figures obtained after applying the corrections (given on page 78) to mean places calculated from the Sūrya Siddhānta, given in the *Pañca Sidahāntikā* of Varāha. From this it is proved beyond doubt that the planetary positions cited cy Bhāsvatī are those obtained by applying the Varāha's corrections to the places derived from the original Sūrya Siddhānta. The annual motions of planets are also given in the same way.

True Aries Ingress

The calculation of mean places, according to this work, is based, not on ahargaṇa but on 'varṣagaṇa' (*i.e.* the number of years elapsed), and it has already been pointed in the discussion on Kamalāmārtaṇḍa (page 107) that this method is very convenient. All other Karaṇa works which advocate the calculation of mean places from 'varṣagaṇa' start with the moment of mean Aries Ingress ; but this work starts with the moment of the true Aries Ingress. In preparing his plenetary tables Keropant has based the calculation of the planet's places on the true Aries Ingress.

Centisimal System

Śatānanda's work has one more speciality, viz. that he has adopted a centi-

*The ahargaṇa for verifying the epochal position given in Bhāswatī as calculated from (the epoch of) Pañca Siddhāntikā comes to 216962. One can easily see how labrious it would be to do the multiplication and divisions with this figure. If on the other hand the work had given the rates of annual motion, the basic figure would have been (1021—427)=594 and the planetary calculation would have been far more easy.

simal system, for starting the epochal positions and the multipliers and divisors required in the calculation of the motions of planets. Ir doing so he has mentioned the positions and motions of the Sun and the Moor in terms of Nakṣatras and those for Mars and other planets in terms of Rāśis (Signs). The author quotes two examples of this. The rate of annual motion of the moon has been given as $995\frac{5}{6}$—. These are centisimal parts. This number, divided by 100, would give the required number of Nakṣatras. This would give $\frac{995\frac{5}{6}\times 800}{100}=7966\frac{2}{3}$ minutes$=4^s12°46'40.''$ The adoption of the motion in centisimal units such as $995\frac{5}{6}$ involves much less labour than that involved in adopting the motion in terms of signs, degrees, etc. Another example. The epochal position of Saturn is given as 594. This is given in terms of signs. The figure 594 when interpreted as so many centisimal units would give

$$\frac{594}{100}=5^s28°12'$$

This system is somewhat similar to the present decimal system. One cannot say if the author of this Karaṇa work adopted the name Śatānanda because he loved the Śatāṃśa (centisimal) system.

Contents

The Bhāswatī consists of the following eight *Adhikāras* (chapters)—(i) 'tithi dhruva' (ii) 'grahadhruva' (iii) true tithi (iv) true places of planets (v) three problems (vi) lunar eclipse (vii) solar eclipse and (viii) graphs. These consist of about 60 verses in all in different metres.

Bhāsvatī has assumed Śaka 450 as the zero precession year, and 1′ as the annual rate of precession.

Commentaries

There is a commentary on Bhāsvatī written in Śaka 1417 by Aniruddha of Vārāṇasī from which it appears that there were many other commentaries on it written before. Mādhava's commentary was written about Śaka 1442. He was a resident of Kanauj, (Kānyakubja). Another commentary was written by Gaṅgādhara in Śaka 1607. There is yet another commentary dated about Śaka 1577. Colebrooke says that Balabhadra's commentary was written in Śaka 1330. From the catalogue* of Sanskrit books prepared by Aufrecht, the title of this commentary appears to be Bālabodhinī. According to Aufrecht's Catalogue there are following additional commentaries on Bhāsvatīkaraṇa :—Bhāsvatīkaraṇapaddhati ; Tatvaprakāśikā by Rāmakṛṣṇa ; Bhāsvatīcakraraśmyudāharaṇa by Rāmakṛṣṇa ; Udāharaṇa by Śatānanda ; Udāharaṇa by Vṛndāvana. Similarly, there are commentaries by Acyutabhaṭṭa, Gopāla, Cakravipradāsa, Rāmeśwara, Sadānanda and a "prākrit" commentary by Vanamāli.

Most of these commentators hail from Northern India. It shows that Bhasvatīkaraṇa was well known on that side. It is not at present known there, nor did I come across a reference to it in any other work.

KARAṆOTTAMA

Date

This Karaṇa work has been mentioned at several places by Mahādeo in his commentary on Śrīpati Ratnamālā. Mahādev quotes from this Karaṇa on

*The German Oriental Society has published at Leipzig in the year 1891, a very big extensive catalogue of Sanskrit books (Catalogus Catalogorum) prepared by a Germano scholar. Theodor Aufrecht, on the basis of 56 long lists of Sanskrit books, 19 of which Contained particulars of books at different places in Europe and 37 of those available in India.

precession. "Śaka vasutryambara candra hīnaḥ", which means, "Śaka diminished by 1038". Similarly, he quotes also the following lines from it :— (i) "kalā rūpā yātāḥ karaṇaśaradaḥ sa śatayutā" and (ii) "Karaṇottamādau cāpyāyanāṃśā daśasamkhyāḥ", meaning (i) The precession in Kalās (minutes) is 600, equal to the years elapsed before the date of (compilation of) the Karaṇa and (ii) the ayanāṃśas adopted by the Karaṇottama at its beginning are 'ten'. This clearly shows that the work, Karaṇottama, was compiled in Śaka 1038. That Śaka 438 was taken to be zero precession year, and that the annual rate of precession was 1′. A statement from the Tājakasāra (Śaka 1445) viz that the places of planets should be calculated from Sūryatulya, Karaṇottama or Rāja Mṛgāṅka has already been given on page 41. Out of those Sūryatuly a might have been a work following the Saurapakṣa ;Rājamṛgāṅka has alreadey been shown to belong to Brahmapakṣa. Hence, it seems that the third, Karaṇottama, probably belonged to Āryapakṣa ; that it was in use in Śaka 1445, is obvious from the Śaka year of Tājakasāra. I have not read or heard of the work being available in use anywhere at present.

MAHEŚVARA

He was the father of Bhāskarācārya, the famous astronomer and author of Siddhānta Śiromaṇi. His date of birth may be about the year Śaka 1000 and his works may have been written about the year 1030 to 1040. The account of his ancestry will be found later in the account of Bhāskarācārya. According to the inscription of Ananta Deva, his great grandson, he compiled "Śekhara" a Karaṇa work, Laghujātakaṭikā, a work on astrology, and the work entitled Pratiṣṭhā vidhidīpaka (see account of Bhāskarācārya). Vṛttaśata is another work written by him. It may be identical with the Muhūrta work named Vṛttaśata.

ABHILAṢITĀRTHA CINTĀMAṆI

THE AUTHOR

King Someśwara III of the Uttara Cālukya dynasty, who was otherwise known as Bhulōkamalla or Sarvajñya Bhupāla, compiled the work "Abhilaṣitārtha Cintāmaṇi or Mānasollāsa. It contains a number of subjects of which astronomy is one. The work has adopted Śaka 1051 as the epoch for planetary calculation. The following lines are found written with reference to it :—

एकपंचाशदधिके सहस्रे १०५१ शरदां गते । शकस्य सोमभूपाले सति चालुक्यमंडने ।।
समुद्ररसनामुर्वी शासति क्षतविद्विषि । सर्वशास्त्रार्थसर्वस्वपायोधिकलशोद्भवे ।।
सोम्यसंवत्सरे चैत्रमासादौ शुक्रवासरे । परिशोधितसिद्धांतलब्धाः स्युर्ध्रुवका इमे ।।*

Translation :—

It appears from this that the work has given epochal positions for Friday, the first lunar day of the bright half of Caitra of the above Śaka year, and the places of planets have been calculated from the ahargaṇa. As the author has not actually seen the work, it is not known from what Siddhānta-work the planet's places have been calculated.

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*See Prof. Bhandarkar's *History of the Deccan* (English) Journal of the Royal Asiatic Society, New Service.

OTHER WORKS AND AUTHORS BEFORE ŚAKA 1072

Bhāskarācārya's Siddhāntaśiromaṇi cites the names of a number of works, among which there are some which have not been described so far.

Mādhava's Siddhānta Cūḍāmaṇi has been referred to twice in Śiromaṇi (see pages 234 and 269 of Pandit Bāpūdeva's book). This Siddhānta is not now available.

Bhāskarācārya's 'Bījagaṇita' (algebra) refers to Brahmā and Viṣṇu Daivajñya as writers on algebra who lived before him. Their works are not available at present. Of them, Brahmā may be the author of Karaṇaprakāśa.

BHĀSKARĀCĀRYA

He was a very famous astronomar. Not only is his fame resounding throughout our country for the last 700 years, but it has reached even the foreign countries. A brief account of his work will now be given.

He has the Siddhānta Śiromaṇi and the Karaṇa Kutūhala, two astronomical works, to his credit. He writes in the Śiromaṇi.

HIS DATE

रसगुणपूर्णमही १०३६ समशकनृपसमयेऽभवन्ममोत्पत्तिः
रसगूण ३६ वर्षे मया सिद्धांतशिरोमणी रचितः ।। ५८ ।।

गोले प्रश्नाध्याये

Translation :—

"I was born in the Śaka year 1036 and I compiled the Siddhānta Śiromaṇī when I was 36 (58th verse)."

This shows that the year of his birth was Śaka 1036 and that he compiled Siddhānta Śiromaṇi when he was in his 36th year. The epoch adopted for the Karaṇakutūhala is Śaka 1105. From this, he appears to have compiled it in that year. He has himself written a commentary named Vāsanābhāṣya on two chapters of the Siddhānta Śiromaṇi, Grahagaṇita and Golādhyāya. At one place (in the chapter on the soli-lunār parallels of declination) in it he observes "I have similarly quoted the 'Śarakhaṇḍakas' in the karaṇa work"; and he has, at some places in the commentary adopted 11° as the ayanāṃśa. This ayanāṃśa value of 11°, according to his view, was true in Śaka 1105. So he seems to have written the commentary about the Śaka year 1105. However, a part of the commentary may have been written before this and some portion may possibly have been written along with the original Siddhānta. He compiled the Karaṇa work in the 69th year of his age and a portion of the commentary also was written then. This speaks of his energy and intelligence at such a ripe age. Such people are very rare in our country at present. His works and other works also contain so much evidence about his date that there is absolutely no doubt about it.

ANCESTRY

Bhāskarācārya has recorded a brief history of his ancestors and has mentioned the place of his residence in the following verses :—

आसीत् सह्यकुलाचलाश्रितपुरे त्रैविद्यविद्वज्जने नानासज्जनधाम्नि विज्जडविडे शांडिल्यगोत्रो

द्विज: ।

श्रौतस्मार्तविचारसारचतुरो नि:शेषविद्यानिधि: साधूनामवधिर्महेश्वरकृती

दैवज्ञचूडामणि: ।। ६१ ।।

तज्जस्तच्चरणारविन्दयुगलप्राप्तप्रसाद: सुधीर्मुग्धोद्बोधकरं विदग्धगणकप्रीतिप्रदं प्रस्फुटम् ।

एतत् व्यवतसद्गुवितयुक्तिवहुलं हेलावगम्यं विदां सिद्धांतग्रथन कुबुद्धिमथनं चक्रे

कवि र्भास्कर: ।। ६२ ।।

गोले प्रश्नाध्याय:

Translation :

(61) There was a Brāhmaṇa, Maheśvara by name, and belonging to Śāṇḍilya 'Gotra', who lived in the village of Vijjadavida, which was sheltered by the ranges of Sahyadri mountains, and which was inhabited by learned men well versed in the three Vedas. He was the formost among astrologers and best of virtuous persons, a treasure of all knowledge and shilled in the study of the Śruti and Smṭri works.

(62) The poet Bhāskara, who was his son and worshiped his feet was very intelligent and he compiled a Siddhānta work which was aimed at being the enlightener of the ignorant and very much liked by the scholars, which was full of true and clear statements, accompanied by reasoning,which was easily intelligible to learned men and antidote to wrong thinking.

It is clear from this that his gotra was śāṇḍilya ; his father's name was Maheśvara from whom he got his learning. His place of residence was Bijjada-vida, near the Sahyadri mountains.

There is a village named Pātan 10 miles S. W., of Calisgaon, in Khaṇḍeś ; at present it is a deserted place. In that village there is a stone inscription* in the Bhavāni's temple. Cangadeo, a grandson of Bhāskārācārya was an astronomer at the court of king Singhaṇa of the Yādava dynasty. This Singhana (Siṃha) ruled at Devagiri from Śaka 1132 to 1159. Cangadeo built a *math* (monastery) at Pātan for the teaching works of Bhāskarācārya and those of his descendants. King Saideva of Nikhumbha dynasty, a feudal king of singhana made an endowment for the maintenance of this monastery in Śaka 1129

*The Late Bhau Ḍaji discovered the inscription and published it in the journal of the R. A. So, N. S. Vol. I p. 414 ff. It was again printed well on p. 340 ff, Vol I, of *Epigraphia Indica*, and Pātan, the name of the village occurs in it.

and his brother, Hemadi, also made a grant. This information can be obtained from the above inscription. Cangdeva has drafted the contents of the inscription, a few years after Śaka 1128. The monastery does not exist now; but one finds traces of its existence. This inscription gives an account of the forefathers and successors of Bhāskarācārya as follows :—

शांडिल्यवंशे कविचक्रवर्ती त्रिविक्रमोभूत् तनयोस्य जातः ।
यो भोजराजेन कृताभिधानो विद्यापतिर्भास्करभट्टनामा ।। १७ ।।
तस्माद्गोविन्दसर्वज्ञो जातो गोविन्दसंनिभः । प्रभाकरः सुतस्तमात् प्रभाकर इवापरः ।। १८ ।।
तस्मान्मनोरथो जातः सतां पूर्णमनोरथः । श्रीमानमहेश्वराचार्यस्ततोऽजनि कवीश्वरः ।। १९ ।।
तत्सूनुः कविवृन्दवन्दितपदः सद्वेदविद्यालता-
कंदः कंसरिपुप्रसादितपदः सर्वज्ञविद्यासदः ।
यच्छिष्यैः सह कोऽपि नो विवदितुं दक्षो विवादी क्वचि—
च्छ्रीमान भास्करकोविदः समभवत्सत्कीर्तिपुण्यान्वितः ।। २० ।।
लक्ष्मीधराख्योऽखिलसूरिमुख्यो वेदार्थवित् तार्किकचक्रवर्ती ।।
क्रतुक्रियाकांडविचारसारविशारदो भास्करनन्दनोऽभूत् ।। २१ ।।
सर्वशास्त्रार्थदक्षोऽयमिति मत्वा पुरादतः । जैत्रपालेन यो नतिः कृतश्च विबुधाग्रणीः ।। २२ ।।
तष्मात् सुतः सिंघणचक्रवर्तिदैवज्ञवर्योऽजनि चङ्गदेवः ।
श्रीभास्कराचार्यनिबद्धशास्त्रविस्तारहेतोः कुरुते मटं यः ।। २३ ।।
भास्कररचितग्रन्थाः सिद्धांतशिरोमणिप्रमुखाः ।।
तद्वंश्यकृताश्चान्ये व्याख्येया मन्मढे नियमात् ।। २४ ।।

Translation :—

(17) Trīvikrama, the best of poets, was born in the Śāṇḍilya family. A son was born to him ; he was named Bhāskarabhaṭṭa and was made the 'Master of learning' by king Bhoja.

(18) From him was born a son Govinda, who resembled Govinda (Lord Kṛṣṇa), from whom was born a son, named Pravākara, who was another Prabhākara (Sun).

(19) From him was born Manoratha who was the fulfiller of "manorath's" (i.e. aspirations) of good men, and the great poet Maheśvara was born from him.

(20) His son, a scholar was so great and famous that his feet were worshipped by groups of scholars, he was the fruit borne by the creeper in the form of learning. he was the store of all knowledge, and he attained so much fame and

was so great that there could rarely be found any one on earth to debate even with his disciples.

(21) Lakṣmidhara was the son of Bhāskara. He was at the helm of all learned men, who interpreted the Vedas and was the leader of logicians and was an expert in the science of 'mīmānsā'.

(22) He being known to be well versed in all sciences was invited by king Jaitrapāla to his court, and was made the leader of all scholars.

(23) From him was born a son named Cangadeo, who was the senior most astrologer at the court of Emperor Singhana. He constructed a monastery with the intention of propagating Bhāskārācārya's works.

(24) All the works compiled by Bhāskara, the chief of which was the Siddhāntaśiromaṇi, and also the works compiled by his descendants, are to be regularly studied in my monsatery.

Bhāskarācārya's genealogical table, prepared on the basis of the above verses is given in the margin :—

Trivikrama
1
Bhāskara Bhaṭṭa
1
Govinda
1
Prabhākara
1
Manoratha
1
Maheśvara
1
Bhāskara
1
Lakṣmidhara
1
Canga Deo

The gotra and the name of Bhāskara's father in this agree with those given by Bhāskarācārya himself. According to the inscription, the sixth person upwards from Bhāskarācārya in the table, was the tutor to king Bhoja Bhāskara, the author of Śiromaṇi, was born in Śaka 1036. Reckoning 20 years as the average for a generation, Bhāskara, the tutor of Bhoja, may be taken to have been born in Śaka 936. Hence it was not impossible for him to be the tutor of king Bhoja, the author of Rājamṛgāṅka, who lived in Śaka 964. The inscriptions further says that Lakṣmidhara, the son of Bhāskara. the author of Śiromaṇi, was invited by king Jaitrapāla to his court and that his grandson, Cangadeo, was astronomer at the Court of Emperor Singhana. Jaitrapāla of Yādava dynasty ruled* at Devagiri from Śaka 1113 to 1132 and his son Singhana ruled from Śaka 1132 to 1169.

There is a village named Bahāl, 10 miles north of Calisgaon, in Khaṇḍeś, near the river Girana. There is an inscription in this villge in the temple of goddes Sārajā. According to this inscription, Maheśvara was the son of Manoratha, of Śāṇḍilya gotra ; his son was Śrīpati who had a son, named Gaṇapati. His son Anantadeo was the Head Astrologer at the Court of King Sinha (Singhana) of Yādava dynasty. In Śaka 1144, he built the above mentioned temple** of the goddess. It was he who got the inscription carved. This description of ancestry agrees quite well with that given in the Cangadeo's inscription. The first ancestor named in Cangadeo's inscription, is the author of the work, 'Damayanti Kathā'.

*See Prof. Bhandarkar's *History of the Deccan*, (English) p. 82.

**This inscription is reproduced on p. 112, Vol. III, *Epigraphia Indica*. The inscription states Dwārajā to be the name of the goddess.

THE PLACE OF RESIDENCE

Bhāskarācārya has not stated that he was patronised by any king, nor do we get such information in either of the two inscriptions. According to his statement, Vijjalaviḍa, was the place of his residence. The last two letters of this word suggest that Bīḍ might have been the place. But Bīḍ is a place in the Nizam state, 80 miles to the east of Ahmedanager. It is not situated near the Sahyadri ranges, and it is learnt from enquiry that there are no descendants of Bhāskarācārya living there at present. The Līlāvatī of Bhāskara was translated in Persian, by Akbar's orders in 1587 A.D. (Śaka 1509). The translator has stated in it that the birth place of the author was Bidar in the Deccan. Bidar is a place about 100 miles to the east of Sholapur* in the Nizam State, but it is not near the Śahyadris. It is a place 30 miles to the east of the well known city of Kalyan. The kings of the cālukya dynasty were ruling at Kalyan at the time of Bhāskarācārya. Even though such a great kindgom existed so near, nothing is mentioned anywhere about the association of Bhāskarācārya with it. From this, we may conclude that Bidar was not Bhāskarācārya's place of residence.

It is stated in the 22nd verse of the Canga Deo's inscription that " king Jaitrapāla called Lakṣmidhara, son of Bhāskarācārya from the town, 'Pātan'. The village of Pātan is very near to Devagiri (Daulatabad), the capital of the Yādava Kings and it is near the Candwad hills which are off shoots of the Sahyadris ; that is, it is " sheltered by the Sahyadri range ", in the words of Bhāskarācārya. The village of Bahāl where Anant-Deo, a descendant of Bhāskara built the temple, is only about 20 miles from Pātan. This shows that Bhāskarācārya's original place of residence was, beyond doubt, the village Pātan itself or some village near it bearing some such name as Vijjalaviḍa. It is not known at present.

Subject matter of Siddhānta Śiromaṇi

The *Siddhānta Śiromaṇi* is divided into four main parts which are also called Chapters. Each part has a number of chapters in it. The first part is termed as the 'Pāṭīgaṇita' or Līlāvatī, by the author. This can be said to be an independent work on arithmetic and mensuration.. It consists of about 278 verses. In between are also given explanations of examples in prose. In the beginning are given in it some tables of various measures ; next follow the terms for the places of digits in a number up to ' parārdha ' which is the 18th place. Next come the eight fundamental operations, addition, subtraction, multiplication, division, square and square root, and cube and cube root. They are termed ' parikarmāṣṭaka '. Then come subjects like, fundamental operations for fractions and those for zero, ' iṣṭakarma ' (unitary method), rule of three, rule of five, progressions etc. Similarly, these are followed by areas and volumes of different figures and solids. Next come subjects like " kuṭṭakagaṇit, pākṣika viparyaya and sarvāmśika viparyaya ", amongst which is given an example of special importance. " A peacock was sitting on a pole, 9 cubits in height. It saw a serpent at a distance of 27 cubits, approaching a hole at the foot of the pole. It jumped to catch the serpent. Both moved at the same speed. How far away from the pole will they meet? " The answer given is ' 12 cubits away from the pole '. This answer is correct if the peacock is supposed to have

*See Pott's Algebra (1886) Sec. II.

flown along the hypotenuse of the right angled triangle i.e. 15 cubits in a straight line. But it is worthnoting that the important mathematical idea that the path of a flying peacock would be a curve much different from the circumference of a circle which is not found in other Sanskrit works, had occurred to Bhāskarācārya. It is needless to say that such popular beliefs as that one can count the leaves of a tree by studying Līlāvatī, are baseless ; but they indicate people's reverence for the work. The second part of the work is known as 'bījagaṇita' (Algebra). It contains the following subjects :— the addition etc. of positive and negative numbers, of unknown quantities and of surds. Then come the chapters on subjects like 'kuṭṭaka' and 'varga-prakriti', simple equations of one unknown quantity, simultaneous equations of more than one unknown and equations involving squares and higher powers of one or more unknown quantities. This consists of about 213 verses in all, with some prose portions in between.

The parts known as 'golādhyāya' and 'gaṇitādhyāya' are devoted to astronomy. The first part treats of all subjects related to planetary calculations which have been mentioned in the list of Adhikāra given in the Introduction. The number of verses in it, including those in the commentary, is stated to be 4346. The part known as 'golādhyāya' deals with the theory of all questions discussed in the 'gaṇitādhyāya', a description of the three worlds, a chapter on instruments of observation etc. The number of verses mentioned is 2100. In the end is given a very short but important chapter named "jyotpatti". In the middle is given a short chapter entitled 'description of seasons' ; it has been compiled by Bhāskarācārya only to exhibit his poetic gift.

His Capability

Bhāskarācārya has adopted from the Brahmasiddhānta the numbers of revolutions and other elements of all planets given in the chāpter on mean places and the degrees of epicycles in the chapter on true places. The corrections to be applied to mean positions of planets have been taken in toto from the work 'Rājamṛgāṅka'. Even the precessional motion has been taken from earlier works. In short, there is nothing new in Bhāskarācārya's works which is obtainable by observation ; but his work is full of knowledge obtainable only after deep study. This sort of knowledge is the origin of the theory of the Science of astronomy. The work Siddhāntaśiromaṇi has reached such a high degree of excellence on account of various simplified methods and the explanation of their underlying theory, covering all subjects from the trifling calculation of planets' places from 'ahargaṇa' to abstruse questions like that of parallax and the sine theory, that we can really understand the essence of Indian astronomy by reading even this single work ; and it appears that it is on account of this Bhāskarācārya became so very famous. Several works of varying quality might have been thrown into the background because of this work. In view of the fact that even the Brahma Siddhānta which was revered by Bhāskarācārya like a preceptor, was surpassed by Bhāskara Siddhānta, one can easily guess how many other authors might have been consigned to oblivion because of Bhāskara's works. The period from Āryabhaṭa I to Bhāskarācārya is regarded as the most brilliant period so far as the development of Indian Astronomy is concerned. It is during this very period that the Khaliphs of Baghdad in their days of prosperity invited astronomers from India, got the Hindu works translated into Arabic and Latin, and the Arabs and Greeks became disciples of Hindus. It was in this very period that the problem of 'Ayana' motion was fully studied. Several authors of works might have

flourished in this flourishing period of astronomy ; but some of them are now known only in name, while some others are not even so lucky. It is no doubt due to the march of time ; but it is felt at the same time that Bhāskarācārya was responsible for this to a great degree. No other author of equal calibre was born after him. Bhāskarācārya's works are well known in every nook and corner of the sub-continent of India. Not only this, but they have been, translated also even in foreign languages. But it is the misfortune of our country that such a genius failed to make any of the important discoveries made in Europe in modern times or even lay the foundation of at least one of them. Bhāskarācārya did not make any efforts in respect of observation. The author inclined to believe even from his meagre experience that if he had done it, his intelligence which was devoted to the task of merely explaining theories like a commentator would have definitely been diverted to new discoveries.

His works contain nothing new ; still, because he has devoted all his intellectual power to theory, his works do contain some new discoveries which are obtainable by study and not by observation. To him the knowledge of the sphere was at his fingure's ends. He has suggested a number of new methods in the chapter on three problems and has shown his ingenuity in dealing with several questions in them. Earlier astronomers had not described, in their study of the gnomon, the method of calculating the length of the shadow in any whatever direction but he alone has described it. He has remarked, " Earlier astronomers had been labouring under a delusion in respect of the calculation of the Mahāpāl (Soli-lunar parallel of declination); Idescribed the correct method". Earlier astronomers appear to be regarding the arc of the latitude to be lying along the declination circle, that is perpendicular to the equator but he has clearly shown that latitude is perpendicular to the ecliptic. The correction known as ' udayantar ' is one of his discoveries. It is briefly described here :—

" When finding planets' places from the ahargaṇa, the days are all supposed to be of equal length ; but actually they are not so. Even at the equator, the days are somewhat longer or shorter than 60 ghaṭis (i.e. 24 hours) and this causes the difference between the moments of mean and true sunrise. The places of planets calculated from the ahargaṇa are true for mean sun rise. To deduce their places true for the true sunrise, earlier writers have prescribed the corrections known as ' bhujantar ' and ' cara '. Bhāskarācārya has prescribed one more correction known as ' udayantara '. The sun's motion in the ecliptic is not always uniform. The time of true sunrise differs from that of mean sunrise according to the equation of centre, that is, the difference between the true and mean longitude of the sun. The correction due to this is called ' Bhujantar '. The earth rotates round its axis : it rotates in the plane of the equator and not in that of the ecliptic. It is on account of this fact, that the 30° arc of the ecliptic does not always require the same time to come above the horizon as an equal arc of the equator. The correction necessary to cover this irregularity has been called 'Udayantara' by Bhāskarācārya and this correction is evidently necessary to be applied. The corrections of ' bhujantara ' and ' udayantara ' together are included into one term called " the equation of time " by the European astronomers. Thus Udayantara was one of the discoveries of Bhāskarācārya. Ranganātha, the commentator of the Sūrya Siddhānta has attempted to show in his commentary on the 59th chapter that this correction was desired by the author of the Sūrya Siddhānta and has remarked that the author had not mentioned it as it was very small. The author of the Siddhāntatatvaviveka has attempted to refute

Bhāskarācārya's argument about the need of the adoption of this correction of 'udayantara', but this attempt has proved futile as it shows sheer obstinacy. The Siddhānta-śiromaṇi discusses new trivial questions other than that of 'udayantara' and has in the discussion pointed out at two or three places, Brahmagupta's error".

Karaṇa Kutūhala

The Karaṇa work, Karaṇa-Kutūhala, has adopted Śaka 1105 as the epocha year. The moment of sunrise on Thursday, the new moon day of Phālguna of Śaka 1104, is the epoch for which the positions are given. The mean places have been calculated from ahargaṇa. Bhāskarācārya regards his work as comparable to Brahma Siddhānta, but as a matter of fact, it is so, only when the corrections recommended by Rājamṛgāṅka are applied. It is also called "Grahāgamakutūhala". It was very well known. Some persons use this for calculation even now. It has already been pointed out that the figures claimed by the author of the Grahalāghava, as belonging to Brahmapakṣa, have been taken from this work. There is a voluminous work called "Jagaccandrikāsāraṇī" containing tables which are used to calculate planets' places according to this work. The *Karaṇa Kutūhala* contains the following ten *Adhikāras* (chapters) (i) mean places (ii) true places (iii) three problems (iv) lunar eclipse (v) solar eclipse (vi) rising and setting (vii) elevation of moon's cusps (viii) conjunction of planets (ix) Mahāpāta (x) pūrvasambhava (possibility of eclipses). These respectively contain 17,23,17,24,10,15,5,7, 16 and 5 verses, making 139 verses in all.

Commentaries

No other astronomical work can boast of having so many commentaries on them as the works of Bhāskarācārya. Some of them deal with all the four sections of the Siddhāntaśiromaṇi. Some others are written on only the first part called Līlāvatī, some on only the second part known as 'Bījagaṇita' and still others deal with the two parts 'grahagaṇitādhyāya' and 'golādhyāya'. The commentaries on Līlāvatī are mentioned below :—

Gangādhara, the son of Govardhana and a resident of Jambusara, has written a commentary called 'Gaṇitāmṛtasāgarī'; it probably belongs to Śaka 1342. This was also known as 'Ankāmṛtasāgari', and the Aufrecht catalogue states that Lakṣmidhara was another name of Gangādhara. Gaṇeśa Daivajña, the author of Grahalāghava, wrote his commentary known as 'Buddhivilāsinī', in Śaka 1467. Dhaneśvara Daivajña has written a commentary called 'Līlāvatībhūṣaṇa'. Mahidāsa has written one in Śaka 1509. The commentary known as Līlāvatīvivṛtti has been written by Muniśvara in about the year 1557. The commentary by Mahidhara, known as Līlāvatīvivaraṇa, refers to Muniśvara ; from this it appears to have been written after Śaka 1557. The Aufrecht Catalogue mentions the following additional commentaries :—

The '*Gaṇitāmṛta Lahari*' by Rāmakṛṣṇa, son of Nṛsimha, (1339 A.D.); the *Pāṭīgaṇita kaumudī*, a commentary by Nārāyaṇa, son of Nṛsimha (1357 A.D.). Manoranjanā by Rāmkṛṣṇadeo, son of Sadādeva ; The *Līlāvatībhūṣaṇa* by Rāmacandra ; *Nisṛṣṭadūtī* by Viśvarūpa ; *Gaṇitāmṛtākūpikā* by Śuryadāsa ; the *Udāharaṇa* by Candraśekhara Patanāyak ; Udāharaṇa by Viśveśwara and commentaries by Dāmodara, Devisahāya, Paraśurāma Rāmadatta, Lakṣminatha, Vṛndāvana, Śrīdhara Maithila etc. Of these, the "Nisṛṣṭadūtī" commentary appears to belong to Muniśvara, because Viśvarūpa was another name of Muniśvara.

The commentaries on 'Bījagaṇita' :—The commentary known as Bījanavāṅkura by Kṛṣṇa, the famous astronomer at the court of Emperor Jāhāngir was written in about Śaka 1524. It is also known as Bījapallava and Kalpalatāvatāra. It is very extensive. There is a commentary known as Bījaprabodha written by Rāmakṛṣṇa, son of Lakṣmaṇa, who was the son of Nṛsiṃha Deo of Amraoti. This Rāmakṛṣṇa calls himself a disciple of Muniśvara. From this it appears that it belongs to about Śaka 1570. The Aufrecht catalogue mentions "Bījavivṛttikalpalatā" by Paramasukha, and '*Udāharaṇa*' by Kṛpārāma, as additional commentaries.

Gaṇeśa Daivajñya, author of the *Grahalāghava*, has written a commentary on "Grahagaṇitadhyāya and Golādhyāya". Gaṇeśa, the great grandson of Gaṇeśa Daivajñya, the author of the *Grahalāghava*, wrote a commentary known as 'Śiromaṇi Prakāśa, about Śaka 1500. The commentary known as Vāsanākalpalatā or Vāsanāvārtika by Nṛsiṃha, a resident of Golagrām, belongs to Śaka 1543. The Marīci commentary by Muniśvara or Viśvarupa is very extensive and the best one. It was written in Śaka 1557. Siddhāntasūryodaya, a commentary by Gopinātha, brother of Raghunātha and son of Bhairava, was written after Śaka 1450.

The following are the commentaries on the complete work of Siddhāntaśiromaṇi :—Sūryadāsa, son of Jñyānarāja, has written a commentary known as *Sūryaprakāśa* on all the four sections. The part of this commentary relating to Līlāvatī and Bīja was written in Śaka 1460. Paramādiśvara, the commentator of Āryabhaṭa I, is said to have written a commentary called Siddhāntadīpikā on the works of Bhāskarācārya. It appears to have been written on all the four sections. The commentary "Mitabhāṣiṇī", by Ranganātha, son of Nṛsiṃha, a resident of Golagrām, was written soon after Śaka 1580.

The Aufrecht Catalogue mentions the following additional commentaries :— The 'Gaṇitatatvacintāmaṇi by Lakṣmidāsa, son of Vācaspati (1501 A.D.) The Udāharaṇa, by Viśvanātha; and the commentaries by Rājagirīpravāsī Cakracuḍāmaṇi, Jayalakṣmaṇa or Jaya Lakṣmi, Maheśvara, Mohandāsa, Lakṣminātha, Vācaspatimitra (?) and Harihara. Most of them might be confined to Grahagaṇitadhyāya and Golādhyāya only.

The *Karaṇa Kutūhala*, has been commented upon by Soḍhala, by Padmanābha, son of Nārmada, and by Śaṅkar kavi. The last commentary has adopted Śaka 1541 as the year for its examples. There is a commentary dated Śaka 1482, which contains an example ; the commentator was a resident of Unnata Durga. The place has 4-48 as the *palabhā* and 60 yojanas west, as *deśāntar* (longitude). The Aufrecht Catalogue mentions the following additional commentaries :—Gaṇitasār conforming to Brahmasiddhānta and written by Keśavārka; 'Gaṇakakumudakaumudī' by Harṣagaṇita; the Udāharaṇa by Viśvanātha, and the commentary by Ekanātha.

There may be* many more commentaries on Bhāskarācārya's works. The Līlāvatī was translated into Persian in Śaka 1509 and the Bīja in Śaka 1597. Colebrooke has published the English translation of Līlāvatī and Bījagaṇita in 1817 A.D. Pandit Bāpudeva Śāstri published an English translation of Golādhyāya in the *Bibliotheca Indica* in 1861 A.D. The translation contains a number of notes. All parts of Śiromaṇi and the Karaṇakutūhala have been printed at several places in our country.

*The author has taken the information about some of the commentaries enumerated above from other books. He has not seen all the commentaries personally.

Mādhava (Śaka 1185) the commentator of Ratnamālā, and other writers have mentioned, 'Bhāskarvyawahāra,' a work on Muhūrta. It may be a work by Bhāskārācārya. A verse of Bhāskara has been quoted in connection with marriages in the commentary on Vivāhapaṭala by Rāma (Śaka 1446). A reference to the work Vivāhapaṭala by Bhāskara was also found in the 'Śārṅgīya' Vivāhapaṭala and in other one or two works ; and a small volume named Bhāskaravivāhapaṭala which is in the Deccan College collection, gives no information other than the author's name. It appears however, that Bhās karācārya might have written a work entitled "*Vivāhapaṭala*".

Anantadeva

He was a descendant of Bhāskarācārya. His inscription at Bahāl dated Śaka 1144, has already been referred to above (page 117). He has mentioned in it that he wrote commentaries on "chandaścityuttara", the 20th Chapter of Brahmagupta's Siddhānta, and on Bṛhajjātaka.

ĀDITYAPRATĀP SIDDHĀNTA

The Mahādevī commentary on Śrīpati's Ratnamālā has quoted some lines from this Siddhānta. The Mahādevī commentary belongs to Śaka 1185. This Siddhānta must, therefore, have been written earlier than this. The Aufrecht Catalogue mentions it as written by Bhojarāja. If it be true, it belongs to about Śaka 964.

VĀVILĀLA KOCCANNĀ

A karaṇa work by Vāvilāla Koccannā, a Telanganā astronomer, belongs to Śaka 1220 ; and the epochal positions in it are given for the afternoon of Thursday, the New Moon day of Phālguna of Śaka 1219. I have calculated the planet's places from the modern Sūrya Siddhānta, and they agree with the author's places completely. It, therefore, clearly shows, that the work has been compiled with the help of the modern Sūrya Siddhānta. The work does not contain the correction to be applied to Sūrya Siddhānta according to Makaranda and other works. Mr. Warren, an European of Madras, compiled a work entitled 'Kāla Saṃkalita' in 1825 A.D. It incorporates the major part of this Karaṇa work and gives some information about it. It appears from this that the work is still in use in Telanganā, and almanacs are prepared with its help. These almanacs are known as "Siddhānta Cāndra-Pañcānga."

GRAHASIDDHI

It is a Karaṇa work. It is also known as Mahādevī Sāraṇī. It has adopted Śaka 1238 as the epochal year, and hence, it appears to have been compiled about that time.

Its History

The author, in the very beginning, observes,

चक्रेश्वराब्धनभश्चराशुसिद्धि महादेव ऋषींश्च नत्वा ॥ १ ॥

which shows that the work was first started by some astronomer, Cakreśvara, and then the imcomplete work was carried to completion by Mahādeva.

Dhanarāja wrote a commentary on it. Mahādeva has recorded his family history in the last 4 verses of the original work ; but the commentator has not commented upon them because the verses are very incorrect. There is a copy of the commentary in the Deccan College collection. The Ānandāśrama has got a copy of the work without a commentary (no. 2086) which contains the same verses in their incorrect form. One comes to know from it that Mahādeva was a Brāhmaṇa, his Gotra was Gautama. Padmanābha was his father's name and Mādhava* his grandfather's name. The Author has come across an old work named 'Jātakasāra', written in Sanskrit and, Gujerati. It has recommended the calculation of planets places from Mahādevisāraṇī. The copy of the Mahādevisāraṇī belonging to the Deccan College Collection was procured at Ahmedābad. The commentator also is the resident of a place near Gujerat, and Mahādeva himself has adopted 4½ as the 'palabhā' for calculating the ascensional difference (cara). It shows that he may have been the resident of a place near Surat in Gujerat, and it appears that the work might have been in use in Gujerat for a considerable period.

Contents

This work contains about 43 verses. They describe the methods of calculating only the mean and true places of planets. The epochal positions are given for the mean Aries Ingress and the work contains tables for calculating mean places of planets from 'varṣagaṇa', which simplifies all calculation. It has given the positions and motions of planets which are comparable to the Brahma Siddhānta, after the corrections mentioned by Rāja Mṛgāṅka are applied.

The Commentary

The commentator has given his account at the end. A portion of it is given below :—

वर्षेनेत्रनवांगभू १६९२ परिमिते ज्येष्टस्य पक्षे सिते-
ष्टम्यां सद्गुण पृथक्यमन्नरयु (?) पद्मावतीपत्तने ॥
राजाहुत्रत्करवैरिनागदमनो राठोडवंशोद्भव:
श्रीमान् श्रीगजसिंहभूपतिवरोस्ति श्रीमरोमंडले ॥
जैने शासन एवमंचलगणे...॥

Translation :—(There are omissions and inaccuracies in the text).

"In the village of Padmāvati, on the 8th lunar day of the bright half of Jyeṣṭha in Śaka 1692........"

"There is the King Gajasiṃha, of Rathoḍ family, who is a Jain and rules.."

From this, the commentator appears to be a Jain. He has given Dhanarāja as his name. He has, in the commentary, calculated the longitude of Sirohi, (a place, 30 Yojana's West of Ujjainī) ; and from this, he seems to be a resident of that place. The name of the commentary is Mahādevī Dīpikā. It is said to contain 1500 verses. The year 1692, mentioned in the above verse, is a Samvat year of the Vikrama era, and hence, the time of the compilation of the commentary comes to be Śaka 1557.

* *See line* 19, Page 316.

NĀRMADA

It has already been observed in reviewing the modern *Sūrya Siddhānta* (Page 43) that there must have been a commentary on the *Sūrya Siddhānta* or some work based on it from the pen of Nārmada. The time of that Nārmada must be Śaka 1300. This point has been discussed further while commenting on the Dāmodarīya bhaṭatulya. The commentary or work is not at present appreciated.

PADMANĀBHA

He was the son of Nārmada mentioned above. His probable date was Śaka 1320, and more information about him has been given in the next para. He has written a work entitled 'Yantra-Ratnāvalī'. The author had with him, its second chapter entitled Dhruvabhramayantra, which bears his (Padmanābha) own commentary.

A review of these works will be found in the Chapter on instruments.

DĀMODARA

Dāmodara has to his credit a work, Bhaṭatulya by name. Its epochal year is Śaka 1339. The author observes,

दामोदरः श्रीगुरुपदमनाभपदारविंदं शिरसा प्रणम्य ।।
प्रत्यब्दशुध्यार्यभटस्य तुल्यं विदां मुदेहं करणं करोमि ।। २ ।।

मध्यमाधिकार:

Translation :—

Dāmodara, after saluting the Lotus-like feet of his Guru Padmanābha, compiles this karaṇa work, comparable to that of Āryabhaṭa, for the pleasure of laerned men(2)

श्रीनर्मदादेवसुतस्य मत्पितुः श्रीपद्मनाभस्य समस्य भावतः ।।
यस्मात् सुसंपन्नमनुग्रहात् गुरोर्भूयादिहैतत्पठनात् प्रदं श्रियः ।। १६ ।।
सच्छिष्यैरसकृत् कृतप्रणतिभिः संप्रार्थितो बीजवित
वक्त्रांभोजरविश्चकार करणं दामोदरः सत्कृती ।। १९ ।।

उपसंहार.

Translation :—May the study of the work made with the favour of my father and preceptor Śripadmanābha, son of Śrinārmadadeva, bring me prosperity. (16)

The virtous Dāmodara, whose lotus face was like the Sun and who is offered continuous prayers by his good disciples, compiled this Karaṇa (work) (19)

———'Conclusion'

From this, it appears that Padmanābha was his father's name, who was also his preceptor and the name of his grandfather was Nārmadadeva. In the Dhruva-bhramayantra mentioed above, the author observes in the beginning.

श्रीनर्मदानुग्रहलब्धजन्मनः पादारविंदं जनकस्य सदगुरोः
नत्वा त्रियामासमायादिबोधकं घ्रुवभ्रमं यंत्रवरं ब्रवीम्यथ ।। १ ।।

Translation :—After saluting the feet of my father and preceptor, who was born because of the favour of Śrīnārmadadeva, I describe the best of the instruments, the Dhruvabhramayantra, which is useful in giving the time at night (1)

and in the end, the following remark is made :—

इति श्री नार्मदात्मजश्रीपद्मनाभविरचितयंत्ररत्नावल्यां
स्वविवृत्तौ घ्रुवभ्रमणधिकारो द्वितीयः ।।

Translation :—So ends the second chapter on Dhruvabhramaṇa, in his self-written work Yantra Ratnāvalī, which is compiled by Śrīpadmanābha, son of Śrīnārmada.

It appears from this, that Nārmada was the name of Padmanābha's father and this leads one to believe, beyond all doubt, that this Padmanābha was Dāmodaras father. Dāmodara's work was written in Śaka 1339. Hence, assuming 20 years for one generation, the date of Padmanābha's work comes to be about Śaka 1320. The work, 'Jātakābharaṇa', (see section on 'jātaka' later on) written in about Śaka 1460, refers to the Dhruvabhramayantra, which lends support to the above argument. Although it does not prove beyond doubt that the Nārmada whose verse has been quoted by Raṅganātha (page 43) was the father of Padmanābha, referred to in the above verse. still there is a similarity of names. Padmanābha says that Nārmada, his father, was a scholar and was also his preceptor, and it appears quite probable that he could have been the author of some work. The Nārmada, mentioned by Ranganātha, must have lived before him (Śaka 1525) and this does not give rise to any contradiction ; and the most important fact is that Dāmodara has adopted in his work, Bhaṭatulya, 54 seconds as the rate of annual equinoctial motion. This is the same as in the Sūrya Siddhānta. None of the 'pauruṣeya' (human) authors of works described so far, have adopted this notion except Dāmodara. From this, it seems beyond doubt, that Nārmada who was his grandfather, must also be the author of the commentary on Sūrya Siddhānta. The date of his commentary may be Śaka 1300.

The work 'Bhaṭatulya' has adopted epochal positions for the mean Aries Ingress of Śaka 1339. They agree with those obtained after applying the Lalla's corrections to First Āryasiddhānta. The sides and nodes are given according to the First Ārya Siddhānta. He has adopted 54 seconds as the annual equinoctial motion and Śaka 342 as the zero-precession year. More information about this will be given later on. This work contains the following chapters :—

(i) mean places.
(ii) true places.
(iii) calculation of places of five planets.
(iv) three problems.
(v) lunar eclipse.
(vi) risings and settings and
(vii) conjunctions of planets. It contains, in all, 222 verses in various metres. The author has remarked in the end that the number of verses would be 400, if composed in 'anuṣṭup' metre.

He has dealt with the chapter on 'three problems' very extensively. It consists of 87 verses, which contain some problems also and the figure 5 for the 'palabhā' has occurred a number of times in those problems. The first Ārya Siddhānta does not mention longitudes of stars. The work 'Karaṇaprakāśa which also follows the Āryapakṣa, does not give longitudes of stars. But those given by Dāmodara are some what different from what one finds in all other works. This speaks of his independent discovery in this respect. A more detailed discussion of this will be found further in the chapter on conjunctions of planets.

MAKARANDA

Makaranda is a work containing tables which facilitate the calculation of the almanac. It has been compiled by the astronomer Makaranda himself. In the beginning he observes,

श्रीसूर्यसिद्धांतमतेन सम्यग्विश्वोपकाराय गुरुप्रसादात् ।।
तिथ्यादिपत्रं वितनोति काश्यामानंदकंदो मकरंदनामा ।। १ ।।

Translation :—Makaranda, who is delight incarnate, has, by his preceptor's favour, compiled this work containing tables for calculating Tithi etc., on the basis of the Sūrya Siddhānta for the use of the world.

It shows that this work was compiled on the basis of the Sūrya Siddhānta and that the author was a resident of vārānasī. The ending moments of tithis etc., given in ghaṭis and pala's, when calculated according to this work, are found true chiefly for vārānasī. The Sūrya Siddhānta referred to in this, proves to be the modern Sūrya-Siddhānta from the theory. It is stated in the version printed at Vārānasī that the work had adopted Śaka 1400 as the epochal year. There is no other internal evidence in support of this assertion, nor does the author find any external evidence. There is, however, no reason to doubt its authenticity. Diwakar wrote a commentary on this work named Makarandavivaraṇa about Śaka 1540. The ending moments of tithis etc., and places of all planets are obtained very easily with the help of this work. The author does not describe the system for want of space. In many parts of Northern India, like Gwalior and Vārānasī, almanacs are compiled with the help of this work even at present, and these are used by the local population. This work is printed in Vārānasī. The theory underlying these tables has been explained by Gokulnāth Daivajña in Śaka 1688, and it has also been printed.

The author of Makaranda has recommended a correction for the Sūrya Siddhānta, which has been mentioned already.

KEŚAVA

Gaṇeśa Daivajña, the author of Grahalāghava, has written a commentary on 'Vivāhavrindāvana' which is a work by Keśava. The work, 'Karaṇakaṇṭhīrava', was, according to Gaṇeśa also compiled by the same Keśava. This must have been a karaṇa work but it could not be procured anywhere. This Keśava was an Audicya Brāhmaṇa of Bharadvaja Gotra. The names of his forefathers, beginning from his father in ascending order, were Rāṇaga, Śriyāditya and Janārdana. This Keśava must have lived earlier than the Keśava, the father of Gaṇeśa, the author of Grahalāghava. Nirṇayamṛta, a commentary on Pitāmbara's Vivāhapaṭala, written in Śaka 1446, refers to the

Vivāhavrindāvana. It appears from this that the date of this Keśava could not have been later than Śaka 1400. The work, Vivāhavrindāvana is well known and it is at present available in a printed form. According to the Aufrecht's Catalogue, there is another commentary on the work written by Kalyāṇavarma

KEŚAVA (II)

He was the father of Gaṇeśa Daivajñya, the famous author of Grahalāghava. He was himself a very great scholar. According to the well-known saying, 'Desire success on all fronts, but desire a defeat from the disciple,' it was very creditable to Keśava that Gaṇeśa Daivajñya surpassed him in the matter of planetary calculations. It is evident that his son could not have possessed so much ability, if Keśava had not been a learned man himself. He has to his credit a Karaṇa work named Graha Kautuka, and the Śaka year 1418 has been adopted as the commencing year in it. From this, he appears to have lived about that date. In the work Muhūrtatatva, he remarks at the end,

......गुरुवैजनाथचरणद्वंदे रतः केशवः ।।
नंदिग्रामगतः सुतस्तु कमलज्योतिर्विदग्व्यस्य... ।।

Translation :—This is for "Keśava, who hails from Nandigrāma, who is the son of Kamalākara, who always worships the feet of his preceptor Vaijanātha and who is the leader of astronomers........"

While commenting on this verse, his son, Gaṇeśa Daivajñya observes "From Nandigrāma, a well known village, situated on the eastern shore of the Western sea, of which he was a resident". From this, his father's name appears to be Kamalākara, who was also an eminent astronomer. Keśava got his lessons from Vaijanātha and he was the resident of Nandigrāma on the sea coast in Konkan. This is, at present, a village, in the Janjeera State and is known as Nāndgāon. It lies about 40 miles to the south of Bombay. His gotra, as stated in the account given by Gaṇeśa Daivajñya, was Kauśika, and the name of Keśava's wife was Lakṣmi. The family account of Keśava and Gaṇeśa is found in their other works also.

His works.

The works compiled by Keśava have been enumerated by Gaṇeśa Daivajñya in the commentary on Muhūrtatatva as follows :—

सोपायं ग्रहकौतुकं खगकृतिं तच्चालनाख्यं तिथेः
सिद्धिं जातकपद्धतिं सविवृतिं तार्तीयके पद्धतिं ।।
सिद्धांतेप्युपपत्तिपाठनिचयं मौहूर्ततत्वाभिधं
कायस्थादिजधर्मपद्धतिमुखं श्रीकेशवार्योऽकरोत् ।।

Translation :—"Keśava compiled the following works :—(1) Grahakautuka, with its commentary, the planetary work called 'Grahacālana,' the 'Tithisiddhi', the Jātaka paddhati with its commentary ; the Tartīyapaddhati along with the commentary ; the Siddhānta Pāth containing the arguments and entitled 'Muhūrtatatva' : the religious practices of the Kāyasthas.

Gaṇeśa Daivajñya again writes in the same commentary,

ग्रहकौतुकतट्टीकावर्षग्रहसिद्धितिथिसिद्धिग्रहचालनगणितदीपिकाजातकपद्धतितट्टीकाताजिकप-
द्धतिसिद्धांतपाठकायस्थाद्याचारपद्धतिकुंडाष्टलक्षणादिग्रंथजातनिबंधानंतरमहं केशवो
मुहूर्ततत्त्वं वक्ष्ये,

Translation :—I, Keśava, describes the following works :—[the same list of works as above, with the addition of (1) The definitions of eight kinds of Kuṇḍa (2) Gata nibandha]. This prose extract is quite clear. The works Jātakapaddhati and Tājikapaddhati referred to in this, are at present well known. They are jointly known as the "Keśavi" and many Jyotiṣīs (astrologers) use them. Both the works have been printed. The Muhūrtatatva is also printed. The work Muhūrta Mārtaṇḍa written in Śaka 1493 near Devagiri (Daulatābād) mentions the Jātakapaddhati of Keśava, and a reference to Muhūrtatatva is found in Ranganātha's commentary on the Sūrya-siddhānta written at Vārānasī in Śaka 1525. It shows that these works were extensively used in our country very soon after Keśava.

OBSERVATIONS

Keśava's works on mathematical astronomy appear to have received a setback because of the works written by his son ; but Keśava's rank is very high among astronomers in respect of observations. Our country has produced very few astronomers of equal ability. In the 'Mitākṣara', his own commentary on Grahakautaka, he observes,

ब्राह्मार्यभटसौराद्येष्टापि ग्रहकरणेषु बुधशुक्रयोर्महदंतरं अंकतया दृश्यते । मंदे आकाशे नक्षत्रग्रहयोगे उदयेऽस्ते च पंचभागा अधिकाः प्रत्यक्षमंतरं दृश्यते । ... एवं क्षेपेष्वंतरं वर्षभोगेष्वपि अंतरमस्ति । एवं बहुकाले बव्हंतरं भविष्यति । यतो ब्राह्माद्येष्वपि भगणानां सावनादीनां च बह्वंतरं दृश्यते एवं बहुकाले बह्वंतरं भवत्येव ।...एवं बह्वंतरं भविष्ये: सुगणकैः नक्षत्रयोगग्रहयोगोदयास्तादिभिर्वर्तमानं घटनामवलोक्य न्यूनाधिकभगणाद्यैर्ग्रहगणितानि कार्याणि । यद्वा तत्कालक्षेपकवर्षभोगान् प्रकल्प्य लघुकरणानि कार्याणि । ... एवं मया परमफलस्थाने चंद्रग्रहणतिथ्यंताद्विलोभविधिना मध्यश्चंद्रो ज्ञातः तत्रफल-व्हासवृध्यभावात् । केंद्रगोलदिस्थाने ग्रहणतिथ्यंताद्विलोमविधिना चंद्रोच्चमाकलितं । तत्र फलस्य परमव्हास-वृद्धित्वात् । तत्र चंद्रः सूर्यपक्षात्पंचकलोनो दृष्टः । उच्चं ब्रह्मपक्षाश्रितं । सूर्यः सर्वपक्षेपीषदंतरः स सौरो गृहीतः । अन्ये ग्रहा नक्षत्रग्रहयोगग्रहयोगास्तोदयादिभिर्वर्तमानघटना-मवलोक्य साधिताः । तत्रेदानीं भौमेज्यौ ब्राह्मपक्षाश्रितो घटतः । ब्राह्मो बुधः । ब्राह्मार्यमध्ये शुक्रः । शनिः पक्षत्रयात्पंचभागधिको द् ष्टः । एवं वर्तमानघटनामवलोक्य लघुकर्मणां ग्रहगणितं कृतं ॥

Translation :—The figures as calculated from Brāhma, Āryabhaṭa and Saura Siddhāntas exhibit a vast difference in the positions of Mercury and Venus. Saturn shows an excess of five degrees, when actually seen in the sky at the time of its conjunction with stars and planets and while setting and rising...., similarly, a difference is recorded in epochal positions and in the

annual rates of motions. This difference will become very great as time will elapse, since the Brāhma and other Siddhāntas themselves show a great discrepancy in the numbers of revolutions and the number of seven days etc. Much greater difference will occur after the lapse of a long time.... Hence, the future calculators should calculate planetary places, by adopting the figures of revolutions increased or decreased in conformity with the actual observed phenomena of the conjunction, rising and setting of stars and planets in their own time. Otherwise, short karaṇa works should be compiled by adjusting the epochal positions true for the moment in question. The writer has accordingly found out the mean place of the moon, instead of its maximum equation of centre, by reversed steps, from the observation of the lunar eclipse at the ending moment of the full moon, since, the equation of centre is neither positive nor negative. The moon's apogee was finally fixed by reversing the steps of calculation, after observing the eclipse at the moment of the full moon in the celestial globe of observation, since the maximum correction would neither be plus nor minus. The moon's place was found to be 5 minutes less as compared with that calculated from the Sūrya Siddhānta. The apogee agreed with that of the Brahmapakṣa. The sun's place showed a small discrepancy in the case of all 'pakṣas' ; hence, the writer accepted that belonging to Saurapakṣa. Places of other planets were fixed after actually observing their positions at the time of their conjunctions with stars and planets. Here the writer has taken the Mars and Jupitar as derived from the Brahma Siddhānta and Mercury's place from Brahmapakṣa. Venus was taken as occupying the mean position between the Ārya and Brahmapakṣa. The Saturn was seen to exceed the position given by the three pakṣas by five degrees. Thus the writer has calculated the places of planets by a short method after observing their actual places at the present time.

The writer has not found such a detailed account of results of observations personally taken by any other astronomer and recorded in his own work. As a matter of fact he inclined to think that there never lived another astronomer like Keśava, except the author of the original Sūrya Siddhānta, Āryabhaṭa I, Brahmagupta and the astronomers living in the time of king Bhoja. If he had recorded the day on which the observations were taken and what were the planetary positions found from observation, the record would have been very useful. But it is a matter of regret that tradition never induced the astronomers in our country to record such an account in their own works.

The writer found from calculation that he has adopted in his work, *Graha-kautuka*, such epochal positions and annual motions as agreed with his observations.

Keśava has himself written a commentary on the *Graha Kautuka* and the *Jātakapaddhati*.

GAṆEŚA DAIVAJÑYA

He was a very famous astronomer. The astronomical works of no other astronomer are in use all over India at present as those of Gaṇeśa Daivajñya.

His father's name was Keśava, mother's name Lakṣmi, Kauśika his gotra and Nāndgāon, on the western sea-coast, his place of residence. These facts havlready been stated above.

Viśvanātha, in his commentary "Viśvanāthī" on Graha Lāghava, observes, "the works which Gaṇeśa Daivajñya, my preceptor compiled, have been enumerated by his nephew, the astronomer Nṛsiṃha, in two verses in his commentary on Grahalāghava. They are :—

HIS WORKS

कृत्वादौ ग्रहलाघवं लघुबृहत्तिथ्यादिचिंतामणी ।।

सत्सिद्धांतशिरोमणौ च विवृतिं लीलावतीव्याकृतिं ।।

श्रीवृंदावनटीकिकां च विवृतिं मौहूर्ततत्वस्य वै ।

सत्श्राद्धादिविनिर्णयं सुविवृतिं छंदोर्णवाक्यस्य वै ।। १ ।।

सुधीरंजनं तर्जनीयंत्रकं च सुकृष्णाष्टमीनिर्णयं होलिकाया

लघूपायपातस्तथान्या:........."

Translation :—Gaṇeśa Daivajñya appears to have compiled the following works :—The Grahalāghava, the Laghutithi Cintāmaṇi, the Brihattithi-cintāmaṇi, the Siddhāntaśiromāṇiṭika, the Līlāvatiṭīkā, the Vivāhavṛndā vanaṭikā, the Muhūrtatatvaṭikā, the Śrāddhanirṇaya, the Candorṇavaṭikā, the Tarjanīyantra, the Kṛṣṇāṣṭamīnirṇaya, the Holikānīrṇaya, the Laghupāyapāta (i.e. a table for calculating Mahāpāta), etc.

Even Gaṇeśa has himself mentioned the names of some of his works in his work, *Vivāhavṛndāvanaṭīkā*. They are,

कृत्वादौ ग्रहलायवाख्यकरणं तिथ्यादिसिद्धिद्वयं

श्लोकै: श्राद्धविधिं सवासनतया लीलावतिव्याकृतिं ।।

सप्रेक्षपमुहूर्ततत्वविवृतिं पर्वादिसन्निर्णयं ।।

तस्मान्मंगलनिर्णयाद्यथ कृता वैवाहसद्दीपिका ।।

Translation :—(Not necessary)

This list mentions the additional work, Parvanirṇaya. It is not that these works have been mentioned in their chronological order. Still, the *Grahalāghava* appears to have been compiled first. In this work, Śaka 1442 has been adopted as the epochal year for planetary calculation. At this time he must have been at least 20/22 years of age. In other words his date of birth may have been about Śaka 1420. The work *Laghucintāmaṇi* was written in Śaka 1447 and the Līlāvatiṭīkā in Śaka 1467. The *Pātasāraṇi* shows that it was compiled some time after Śaka 1460. The author has seen a printed Edition of Vṛndāvanaṭīkā and it has mentioned its date of compilation in a curious way. It is given thus :—

The Dates

हायनार्क १२ लवतुल्यमायनं तद्युतीरस ६ युता युतिर्भवेत् ।।

सापि सागर ४ युतोदुपोद्रुकं नत्त्रिनेत्र २३ लव एव पक्षक: ।। १ ।।

पक्ष: सपक्षो २ यदि वासर: स्यात् तदीयरामां ३ शसमस्तिथि: स्यात् ।।

यच्चाखिलैक्यं* कुयमा २१ हतं तत् नंदा ९ धिकं मत्शकवत्सरा: स्यु: ।।

तदयनतिथिपक्षांस्तुल्यतां यांति यस्मिन्.........।।

* (Saṃvatsara	Ayana	Yoga	Naksatra	Pakṣa	Week day	Tithi	Month	
12th	+1st	+19th	+23rd	+1st	+3rd	+1st	+11th)	×21+9=1500.

Translation :—"Take 12 as the number for the saṃvatsara (hāyan). *Add* one (lava) for 'ayana' to it. Add 6 to the sum of these two numbers (i.e. 12+1), so as to obtain (19) as the number of Yoga. Add 4 to the sum which would give 23 as the number of nakṣatras and one (lava) for the pakṣa. If, a pakṣa is added to one more pakṣa (i.e. 1+2) it would give 3 as the number denoting the week day. Take 1 as the tithi number and 11 as the month number. Multiply the sum of all these numbers by 21 and increase the product by 9 (nanda). The result is the Śaka number".

From this we learn that the commentary was completed on Māgha Śukla Pratipada of Śaka 1500, Bahudhānya Saṃvatsara, during Uttarayaṇa, Dhaniṣṭhā, being the nakṣatra and Parigha, the yoga. The calculation for the first lunar day of the bright half of Māgha, in Śaka 1500, shows that it agrees with the given day of the week, nakṣatra and yoga. If this was nearly the time of the compilation of the Vivāhavṛndāvanaṭīkā, the author, must have been about 80 years old. Even it be supposed that he compiled the Grahalāghava at the age of 16, his age still comes to be 75 years. This is not an impossibility. The author however, found a manusript copy of the Vivāhavṛndavanaṭīkā with Raghunātha Jośī at the authors' birth place, the village of Murud in Dapoli tāluka in Konkan, which mentions the date of compilation in the simple line, "Rasanagamanutulye śaka Ānanda varṣe" "meaning", in the śaka 1476, named, "Ānanda Saṃvatsara". This appears to be reliable. The verse "hāyanārka etc......." must have been written by some one else.

GRAHALĀGHAVA

The *Grahalāghava* has adopted Śaka 1442 as the epochal year. The positions have been given true for the moment of sunrise of Monday, the New Moon day of the Phālguna of Śaka 1441 (i.e. the 19th March, 1520 A.D.). They are as follows :—

Planet	s	°	′
Sun	11	19	41
Moon	11	19	6
Moon's Apogee	5	17	33
Moon's node	0	27	38
Mars	10	7	8
Mercury (mean commutation)*	8	29	33
Jupiter	7	2	16
Venus (mean commutation)	7	20	9
Saturn	9	15	21

*The "mean commutation" means the distance of the mean planet from the mean Sun.

Gaṇeśa Daivajñya states how the planets would agree with the positions calculated from ancient works :—

सौरोर्कोपिविधूच्चमंककलिकोनाब्जो गुरुसत्वार्यजो- ॥
ऽसृग्राहू च कुजज्ञकेंद्रकमथार्यः सेषुभागः शनिः ॥
शौक्रचं केंद्रमजार्यमध्यगमितीमे यांति दृक्तुल्यतां ॥

मध्यमाधिकार.

Translation :—(not necessary, since the sense is given in the following para). The places calculated for Sunrise on Monday, the New Moon day of Phālguna of Śaka 1441, according to the instructions given above agree completely. That is, calculated from the modern Sūrya Siddhānta, the places of the Sun, and the Moon's apogee and that of the moon diminished by 9 minutes would agree with the positions given above. Calculated from the Karaṇaprakāśa of the Āryapakṣa, the places of Jupiter, Mars, the Moons' node and that of Saturn increased by 5°, would agree with the positions mentioned above. The anomaly of Mercury agrees with that calculated from the Karaṇakutūhala of Brahmapakṣa; and the anomalies of Venus, as calculated from Karaṇaprakāśa and Karaṇakutūhala agree with the above position when added up and halved. Gaṇeśa has, however, left out seconds of arc in all the position and increased or decreased the minutes in some cases ; hence, in certain cases, there is some discrepancy as far as minutes of arc are concerned. While calculating the places mentioned above, the ahargaṇa for Karaṇaprakāśa comes to 156334 and that for Karaṇakutūhala to 123113*. It is obvious how very laborious it would be to make calculations with these figures of ahargaṇa. Gaṇeśa has advocated the method of calculating planets' places from the ahargaṇa itself ; but he has employed a device by which the ahargaṇa figure is not allowed to increase too much. He has assumed a cycle of the ahargaṇa of 4016 days, since this happens to be the approximate number of days in the period of 11 years; and the planet's mean motion during this period is termed the "dhruva'. The application of this motion** gives the mean place. The ahargaṇa never exceeds the number 4016 because of this device.

HIS SPECIALITY

Another speciality of the *Grahalāghava* is that it has done away with the use of sines and arcs. Inspite of this there is absolutely no harm in saying that this work gives results by no means less accurate than those obtained from any of the earlier Karaṇa works. Modern English works give tables of sines not only for each degree, but even for each minute of arc ; and some works are so compiled that they give the sines of even seconds of arc. Our works give sines of angles of $3\frac{3}{4}$ degrees and their multiples. Thus , the number of tabular sines is 24 ; but the karaṇa works generally give only 9 (at an interval of 10°) or even less. Even though the Grahalāghava has not used the sines, the method of finding the sun's true places, as adopted by Grahalāghava,

* No commentator has pointed out just as the author has done, the particular works from which the different planetary places have been derived by Gaṇeśa Daivajñya.

** The period of 11 years gives a variable number of days ; and the author has so adopted the device that the error corresponding to this variation would not escape.. The explement of the planet's motion in the cycle is given ; if this explement subtracted from the epochal position and the motion for the ahargaṇa added to the remainder, the mean position of the lanet for the given moment.

gives a value even more accurate than that obtained from other Karaṇa works making use of sines ; not only this, but in some cases it gives more accurate values than those Siddhānta works which contain the values for 24 tabular sines. Gaṇeśa has been on the whole, very keen on seeing that the calculations at all stages would be easily done.

It is true that because of this, certain results turn out to be somewhat approximate, but the other karaṇa works also do not fare any better in this respect. In the conclusion Gaṇeśa remarks.

पूर्वे प्रौढतराः कूचित् किमपि यत् चक्रुर्धनुज्ये विना
ते तेनवै महांतिगर्वंकुमृदुच्छृंगेऽधिरोहंति हि ॥
सिद्धांतोक्त मिहाखिलं लघुकृतं हित्वा धनुर्ज्ये मया
तदगर्वौ मयि मास्तु किं न यदहं तच्छास्त्रतो वृद्धधीः ॥

Translation :—(not necessary, since the sense is given in the next para).

The purport of these verses is "Earlier and more advanced astronomers did their calculation work without chords and sines only in very rare cases, and still they boasted *on that account, why then should not the writer (Gaṇeśa) feel proud like them, since he effected the whole calculation of the Siddhānta work without sines and arcs ? But he ought not to boast because he obtained this knowledge only from their works. Gaṇeśa is right in claiming that he incorporated in the Grahalāghava every subject dealt within the Siddhāntas, and that is why, the *Grahalāghava* came to be known as "Siddhāntarahasya'." A number of Karaṇa-works have been found and many of them treat the method of finding the true places of planets only. There are only three or four works like the *Karaṇa-Kutūhala* which help in calculating most of the items metnioned in the Siddhānta's but none of them is as complete and exhaustive as the Grahalāghava. A commentary on this work was compiled by Gangādhara in Śaka 1508 by Mallāri in Śaka, 1524 and by Viśvanātha about Śaka 1534. There are also some more commentaries on it. The author got at Bārśī a copy of the Grahalāghava written in Śaka 1605. It shows that the Grahalāghava very soon came into extensive use, in the country. At present, they make calculations from the Grahalāghava alone in Mahārāṣtra, Gujerat and many parts of Karnatak. This very work** is used by the Deccanis at Vārānasī, Gwalior and Indore. This work appears to be in use in other provinces also. As the methods of calculation in this work are very simple and satisfy the needs of Siddhānta work, they very soon came into extensive use everywhere and it was also natural that they eclipsed the earlier Karaṇa works.

PLANETARY CORRECTIONS

The following table will show how the places of planets, true for the beginning of Śaka 1442, and calculated from the Grahalāghava, are compared with

* In the Adhikāra (Section) on Three Problems in his *Karaṇa Kutūhals*, Bhāskarācārya observes.

"इति कृतं लघुकामुकशिंजिनीग्रहणकर्म विना द्युतिसाधनं ॥ १२ ॥".

" this calculation of shaddow (chāyā udynti) has been effected without the help of sines and arcs ".

** The Government Almanacs published at Indore and Gwalior are calculated with the helf of the *Grahalāghava* and the Tithi Cintāmaṇi, and are used practically every where in the two States. The Grahalāghava almanac is used in the major part of Hyderabad Deccan State.

those calculated from the European works, the basis of comparison being theirr elation to the Sun.

Planet	°	′
Sun	0	0
Moon	—0	2
Moon's apogee	+1	55
Moon's node	—0	17
Mars	+0	44
Mercury's Śīghrocca	+8	21
Jupiter	+0	58
Venus's Śīghrocca	+1	22
Saturn	+1	29

It appears from this that Mercury's place is very erroneous. The places of Venus, Saturn and Moon's apogee show a discrepancy of 1° to 2°. Others show a difference within 1°. The Moon's place is remarkably correct. The place of the Moon's node is not very erroneous. Gaṇeśa's father, Keśava, has already mentioned in the account of his work, about his claims that he ascertained the place of the Moon and Rāhu from the Solar eclipse. It appears that there is such a serious discrepancy in Mercury's place, because, Mercury is not easily observable as it is visible only for a few days in the year. Another fact that must be remembered is that the above errors occur in the mean places of planets. But only the true places of planets are found by actual observation. While considering Bentley's method, it has already been shown on page 30, that the discrepancy in the actual places of planets at the time of the *Grahalāghava* might have been much less.• It has been shown later on in almanacs what is the extent of error seen at present while calculating figures from the *Grahalāghava*.

Gaṇeśa observes that the places of planets calculated from certain works tally with their observed places on application of certain corrections; accordingly he has suggested a correction of 5° for Saturn's place, which is very excessive. Similarly he has proposed a correction of some minutes of arc in the case of other planets also. It is quite obvious, therefore, put forwarded the names of ancient works only by way of nominal support while recording the actual positions of planets in his own time.

Keśava, Gaṇeśa's father had almost prepared the ground for applying corrections to old works by taking observations, as he had noticed discrepancies in the planets' places obtained from the earlier works, and he compiled the Graha Kautuka accordingly; Gaṇeśa observes in Laghu Cintāmaṇi that he finally corrected the planets after observing the loopholes still left in that work. A comparison of Graha Kautuka and Grahalāghava would confirm this statement. In the Chapter on the risings and settings, in Grahalāghava, he remarks :—

पूर्वोक्ता भृगुचंद्रयोः क्षणलवाः स्पष्टा भृगोश्चोनिता ॥
द्राम्यां तैरुदयास्तदृष्टिसमता स्याल्लक्षितैषा मया ॥ २० ''

Translation :—(not necessary)

In this he says that it was his experience that the moments of risings and settings of Venus are found to be true when the kālāṃśas mentioned by earlier astronomers are diminished by two. All these things go to prove that he was himself an observer. One of the legends that has become quite current about him, says that it was not necessary for him to look to the ground, while walking, because his feet had got eyes. This is of course, an impossibility. Still it goes to show that his attention was always directed to the sky while walking. Another legend says that he was always found to be gazing at the sky while sitting on huge slabs of stone on the seashore. This was quite possible. Many such slabs are found on the sea coast in Kankan and it is very convenient to take observations while sitting in such quiet places.

Calibre

Gaṇeśa was perhaps able to produce a work like the *Grahalāghava* which proved more accurate in the light of observation than Graha Kautuka, because his own experience was coupled with that of his father ; and although the methods described in Graha Kautuka are, in some cases, more convenient than those of Grahalāghava, still, in certain other matters, the Grahalāghava is found to be more convenient. Hence, Graha Kautuka may have gone out of use giving place to Grahalāghava. Considering all things I am inclined to think that his father was more competent than Gaṇeśa himself. However, looking only to the utility of the works the *Grahalāghava* is certainly superior because the experience of both father and son have been combined in that work.

The *Grahalāghava* contains chapters on the following 14 subjects:— (1) Mean places (2) True places (3) Places of five planets (4) Three problems (5) Lunar Eclipse (6) Solar Eclipse (7) "Māsagaṇagrahaṇa" (8) Approximate places of planets (9) Risings and settings (10) Shadow (11) Shadow of stars (12) Elevation of Moon's Cusps (13) Conjunctions of planets (14) Mahāpāta. They contain respectively 16, 10, 17, 26, 13, 13, 19, 8, 25, 6, 12, 4, 4 and 14 verses in different metres and 187 verses in all. At present only these 14 chapters are widely known. But the commentaries of Mallāri and Viśwanātha contain a 15th Chapter of 15 verses entitled 'Pañcāṅgagrahaṇa'. Since the 14 chapters already include 4 chapters devoted to eclipses, this must have been considered superfluous and allowed to be lost. Gaṇeśa appears to have purposely sacrified accuracy in certain cases because of his tendency to simplify calculations and hence, he has added two more chapters on eclipses (7th and 8th) even when 2 chapters out of 14 had been devoted to the eclipses of the sun and the moon. The addition was altogether redundant. Grahalāghava appears to also have undergone certain changes in its different versions. In the copy of the *Grahalāghava* written in Śaka 1605, which the author got at Bārśī the 15th Chapter had been omitted while the chapter on 'Pañcatārā contained 3 more verses which discuss some points about planets' risings and settings. These verses are not found in Viśwanātha's commentary. Some verses show variations in readings. Again the Viśwanāthī commentary contains some verses which are not found in the copy of the *Grahalāghava* printed by Kṛṣṇaśāstrī Godbole. A verse describing the method of calculating the moon's latitude accurately is given in the Viśwanāthī commentary and also in Kṛṣṇa Śāstrī's edition, but it was not found in the copy obtained by author at Bārśī. Different copies of the work give the sequence of certain verses in different ways. It is found at present in the chapter on 'nakṣatrachāyā' a

verse, attributed by Viśvanātha to Nṛsiṃha, nephew of Gaṇeśa, but it is not to be found in the Bārśi-copy. Anyway, even though there are some variations here and there, they have not given rise to any perversion so far as the author's original methods are concerned.

Other works

Among other works of Gaṇeśa that are useful for the calculation of the almanac, Bṛhatcintāmaṇi and Laghucintāmaṇi are particularly noteworthy. They are helpful in quickly calculating figures for tithi, nakṣatra, and yoga. If tithi and other items of the almanac (pañcānga) were to be calculated by actually finding the true places of the sun and moon from the *Grahalāghava*, they would require unremitting labour for six months. If the tables prepared for calculating the mean and true positions of the sun and the moon are utilized, even then one would take according to the author's estimate, about 24 days, of ceaseless labour. But the work Laghucintāmaṇi expedites the calculations to such an extent that the tithis, nakṣatras and yogas could be calculated only in three days. The work can be finished still more quickly if the *Bṛhatcintāmaṇi* is used. And inspite of this economy of labour, it is found by comparison that the difference in ghaṭipalas as obtained from Tithicintāmaṇi and those calculated direct with the help of Grahalāghava, never exceeds 30 palas. I do not propose to describe the nature and scope of Tithi Cintāmaṇi* for want of space. No such work was compiled by any one before Gaṇeśa Daivajñya. The work entitled Makaranda which has already been described before (page 127), helps quick calculations ; but its method is somewhat different, and its date is Śaka 1400, still, Gaṇeśa may not have even seen it at all. Hence, there is no harm in giving full credit for originality to the author of the *Grahalāghava* or having produced a work like the *Tithi cintāmaṇi* which is so very useful in calculation and which reduces one's labour to the barest minimum.

Impeachment

Kero Lakṣmaṇa Chatre has accused Gaṇeśa Daivajñya in the following works :—"He simplified calculations by employing easy devices......but, because of this, the results became approximate to that extent and this laid the foundation of future erroneous methods......Another result has been ....that the tradition of studying the Siddhānta works and of taking observations disappeared and the astronomers are deprived of the knowledge of the basic astronomical theory**. There are also some others who accuse the author of the *Grahalāghava* in the same way. But while considering Gaṇeśa Daivajñya's work, it is no use accusing him for his approximate results by comparing his work with the modern European works. It should be considered what could be the best possible achievement with the means available in his time. Keropant Nānā and other critics do not seem to have considered this aspect of the question because there had been no means so far for judging the question whether earlier authors of Karaṇaworks could secure greater accuracy than Gaṇeśa or what original work was done by him with regard to the taking of observations. If the value of his work from this point

*Keropant has, in his tables of Planetary Calculations, described the method of calculating tithi which is exactly the same as that given in Gaṇeśa's Tithicintāmaṇi. The under lying theory has not been explained. But the author has, explained, in an article in the issue of the Indian Antiquary for April 1887, the theory underlying every step of the method together with an illustrative example.

**Introduction to Keropant's Planetary Tables, P-2.

of view be estimated there would be absolutely no room left for accusing Gaṇeśa Daivajñya. Again, if less laborious methods yield the same results as the extremely laborious calculations gave from Siddhānta works, why should not such methods be accepted ? There is no harm in saying that Gaṇeśa was not at all inferior to earlier astronomers in securing accuracy of results for any problem even while attempting to simplify the work of calculatior. Again it will be seen from the relation which the author has so far traced between all the siddhānta and karaṇa works, that Keropant was wrong in accussing Gaṇeśa of having laid the foundation of erroneous methods. If he means to say that the length of the year (adopted by Gaṇeśa) was inaccurate, the error had persisted from the very beginning. The author thinks that there were very few astronomers among the predecessors of Gaṇeśa in whom ingenuity and perseverance were so happily blended.

He was undoubtedly superior to Bhāskarācārya in the matter of observations. Now-a-days the tradition of studying the Siddhānta works is almost lost. Not to speak of the Siddhānta works, one comes across very few astronomers who have thoroughly studied at least the *Grahalāghava* in its entirety. But this is not the fault of Gaṇeśa's works. Later history will show that he was succeeded by many more astronomers who understood the secrets of the Siddhānta works, who themselves compiled the Siddhānta works and who were also observers. Gaṇeśa himself has written a commentary on Siddhānta Śiromaṇi and Līlāvatī. As regards compiling a work on theory, the work was already done by Bhāskarācārya. It is of course true that he was not attracted to make new discoveries of the kind made ir Europe in his time, but it is not proper to blame Gaṇeśa Daivajñya on that account, for the zest for knowledge was, wanirg among the people at large and, for several other reasons, the love of research had very nearly vanished.

Commentaries

There is a commentary on the *Grahalāghava* written in Śaka 1508 by Gangādhara of the Tapar Village. Mallāri Daivajñya wrote his commentary in the year Śaka 1524. It contains the astronomical theory. The Viśvanāthī commentary belongs to Śaka 1534. It contains illustrative examples. The commentary is also known as 'Udāharaṇa'. The last two of these commentaries are printed. Calculations are seldom made from the ***Bṛhat Cintāmaṇi*** because it contains too many tables ; for this purpose of calculation people prefer the Laghu Cintāmaṇi which is printed. It is full of figures and the errors in these figures which have been accumulating for generaticns have now grown to an enormous extent. Most of the tables have been corrected. There is a commentary, Subodhini by name, written on Bṛhat Cintāmaṇi by Viṣṇu Daivajña, which expands the theory. Cintāmaṇi Kānti, a commentary on the *Laghucintāmaṇi*, is written by Yajñeśvara, an astronomer. It contains the theory. The commentaries on the *Muhūrtatatva* and the *Vivāhavṛndāvana* have been printed.* Tarjaniyantra is a work meant to be used for ascertaining time. It is also called the *Pratoda yantra* ; it is commented upon by Sakhārāma. There is another commentary by Gopinātha, a resident of Saṃgameśvar. The name of Gopinātha's father was Bhairava and that of his grandfather was Rāma. This work will be further dealt with in the chapter on instruments.

There are two other Gaṇeśas, different from the author of the *Grahalāghava* ; one of them is the author of the *Tājak Bhūsaṇa*' and the other of the *Jātakālaṃkāra*.

A legend

This account of the author of the *Grahalāghava* will be closed recounting a legend after about him. Keśava, his father, once predicted the moment of an eclipse. The king of the country, who was a yavana, somewhat ridiculed him, as the prediction did not come true. Keśava was very much grieved over this. He, therefore, started a penance in the temple of Gaṇapatī at Nandigrāma. He had grown old at that time. Looking to his sad plight and firm devotion Gaṇapatī told him in a dream that he (Keśava) would no longer be able to continue the work of observing and rectifying the positions of planets and that, Gaṇapatī would therefore himself come to birth as his son to do the work for him. Accordingly, a son was born to him, who was named Gaṇeśa. People at present regard him as an incarnation of God. Two more stories about him have already been told. All such stories indicate the reverence for him on the part of the people. If once an intelligent person comes to be regarded as divine incarnation, the feeling grows strong that his achievement can never be equalled and this very feeling has been mainly responsible for the absence of discoveries in our country.

His Descendants

It appears that many of the descendants of Keśava and Gaṇeśa were also scholars. Ananta, Gaṇeśa's younger brother, wrote a commentary on Varāha Mihira's Laghujātaka, in 'Jaya' Saṃvatsara (Śaka 1456), and Ananta claims that it is shorter and easier than that of Utpala. Ananta had been guided in his studies by his brother Gaṇeśa. It appears from the Viśvanāthī commentary that there was a commentary on Grahalāghava by Nṛsiṃha, Gaṇeśa's nephew, but it could not be procured any where. Gaṇeśa had a son named Keśava, whose son Gaṇeśa wrote Śiromaṇiprakāśa, a commentary on the *Siddhānta Śiromaṇi*. It may have been written about Śaka 1520. A later descendant in his family, namely Keśava, son of Rudra, compiled a work entitled Lagnakalā Pradīpa, in Śaka 1629, the name of the saṃvatsara being Sarvajit.

KALPADRUMA KARAṆA

A reference to this Karaṇawork occurs in the commentary on the Karaṇ Kutūhala, written in Śaka 1482. The commentary shows that the Kalpa druma Karaṇa was compiled by an astronomer, named Rāmacandra, and that he has mentioned a correction to be applied to the Karaṇa Kutūhala. The figures, indicating corrections known as 'Rāmabija' which have been mentioned in the works of Dinkara and Śrīnātha to be described later on, are different from those mentioned by this commentator. From this it appears that the Rāma-corrections mentioned in the works of Dinkara and Śrīnātha must have been different.

LAKṢMIDĀSA—(Śaka 1422)

He wrote a commentary, known as Gaṇitatatvacintāmaṇi, on the Gaṇitādhyāya and Golādhyāya of Bhāskara's Siddhānta Śiromaṇi. It contains 8500 verses, and gives theory and illustrative examples. His gotra was Upamanyu; Vācaspatimiśra, the name of his father; and Keśava, that of his grandfather. The Śaka figure of 1422, adopted by him for the main example, has been taken by him as 'current'. The solved example on eclipse refers to the Kali elapsed year 4599 (i.e. Śaka 1420). The reasons which led him to compile the commentary have been described by him in the following verse :—

शिरोमणिविबोधने सुजननागनाथेरितः सुहृदगुणगणाकरप्रगुणदेवनाथार्थितः ।।
हितैरनधराधवैरपि निजानुजोर्वीधर प्रियप्रतिविधैषयास्मिविविधप्रयत्नोन्मुखः ।।

Translation :—

With a view to please the scholars, being instructed by Nāganātha, requested by Devanātha, by Urvidhara, the younger brother and by all well wishers, the writer is making efforts to explain the Siddhāntaśiromaṇi.

Lakṣmidāsa appears to have been a good poet.

JÑĀNARĀJA—(Śaka 1425)

GENEALOGY

Rāma (of Bharadvāj gotra)
- Nilkanṭha
  - Viṣṇu
    - Nilkanṭha
      - Nāganātha
        - Nṛsiṃha
          - Nāganātha
            - Jñānarāja
              - Sūrya
                - Nāganātha
                  - Gopāla (Jñānarāja)
                    - Rāmchandra
                      - Vijñāneśwara
                        - Puruṣottama
                          - Kāśinātha
              - Cintāmaṇi
          - Ḍhuṇḍhirāja
            - Gaṇeśa

Jñānarāja was born in a famous family of learned men, which can boast of an unbroken tradition of scholar even to this day. A learned gentleman, from Bid in the Nizam State, and Kāśinātha Śāstri by name, once met the author at Bārśi in Śaka 1807. The author had taken notes of the brief history of his family which was told by Śāstrī. Finding that it agreed with the family history of Jñānarāja, he requested him by a letter recently (Śaka 1817) for further information. He sent him some additional information and the genealogical tree. The genealogical table given in the margin has been prepared by the author on the basis of this information, and the note on Jñānarāja in the 'Aufrecht' catalogue, and also on the basis of the information so far gathered by him. The names of only the first five ancestors of the family have been given from the Aufrecht's table. Even on this point the cross-references at three places in the catalogue showed some contradiction. The author has not ed the names which seemed most consistent with the context. The first man, Rāma, noted in the list has been pointed out in the Aufrecht Catalogue as flourishing at the court of King Rāma of Deogiri. In the genealogical table, sent by Kāśinātha Śāstri, the name of Nṛsiṃha's father has been stated to be Daivajñarāja and the list begins from that name. It appears that Nāganātha or some earlier ancestor of the family might have received the title of Daivajñyarāja. The family history recorded below will show that in the list of ancestors sent by Kāśinātha Śāstrī, there must have been a break after Sūrya or before Gopāla.

PLACE

According to the Aufrecht catalogue, Rāma was a resident of Pārthapur. Sūrya Pandit who wrote Amṛta Kūpikā, a commentary on Bhāskara's Līlāvatī, has described his father and grandfather in it. He observes,

आस्ते त्रस्तसमस्तदोषनिचयं गोदाविदर्भायुतेः
क्रोशेनोत्तरतस्तदुत्तरतटे पार्थाभिधानं पुरं ।।
तत्राभूदगणकोत्तमः पृथुयशाः श्रीनागनाथाभिधो
भारद्वाजकुले सदैव परमाचारो द्विजन्माग्रणीः ।। १ ।।

Translation :—"Pārthapur, a village situated on the northern bank of river Godāvarī, about 2 miles away from the confluence of the Godāvarī and the Vidarbhā, there lived a Brāhmaṇa astronomer, named Nāganātha, belonging to Bharadvāj Gotra."

In the comentary on Bhāskara's 'Bīja' he observes :—

गोदोदक्तटपूर्णतीर्थनिकटावासे तथा मंगला...
गंगासंगमतस्तु पश्चिमदिशि क्रोशांतरेण स्थिते ।
श्रीमत्पार्थपुरे बभूव.........श्रीनागनाथाभिधः ।।

Translation :—(not necessary, since it carries the same sense as the above verses).

We find at present, a village named Pātharī near the north coast of Godāvarī and about 70 miles to the east of Paiṭaṇā. This is the same as pārthapur. It is about 85 miles to the S.E. of Deogiri (Daulatābād). The river Vidarbhā was probably known by another name Mangalā. The above description shows that this Pārthapur was about 2 miles to the N.W. of the confluence of this river and the Godāvarī. Kamalākara Daivajña says while describing Pātharī (See note on Viṣṇu later on) that the city was located in the Vidarbhā country, and it was the capital city of kings and was situated 16 yojanas to the S.E. of Deogiri. Reckoning one yojana as equal to 5 miles, the figures 16 yojanas appear to be correct. Some other works written during this period have also named the country surrounding Pātharī as Vidarbhā country.

DATE

The epochal positions which Jñānarāja has given in his work, Siddhānta Sundara, are true for Śaka 1425. This was evidently his date. Assuming 30 years for each generation, the date of Rāma, the first ancestor in the genealogical table comes to about Śaka 1215, and it agrees with that of king Rāma of Deogiri.

Jñānarāja has written a work on astronomy, called Siddhānta Sundara. I have seen the main parts of Siddhānta Sundara, viz., Golādhyāya and Gaṇitādhyāya. (Book No. 4350 in Ānandāśrama). The Golādhyāya in it contains 6 chapters: 'Bhuvanakośa', 'Madhyagatihetu,' 'Chedyaka', 'Maṇḍalavarṇana', Yantramālā and 'Rituvarṇana'. It contains respectively 79, 30, 21, 16, 44 and 34 verses. The Adhyāya on 'gaṇita' (mathematics) contains the following *Adhikāras* :—Mean places, true places, three problems, probability of eclipses, lunar eclipse, solar eclipse ; risings and settings of planets, shadow of stars,

elevation of Moon's cusps; planetary conjunctions and Mahāpāta. They contain 89, 48, 43, 7, 40, 16, 19, 20, 18, 10 and 11 verses respectively. The Siddhānta Sundara has a commentary compiled by Cintāmaṇi, the son of Jñānarāja ; and a reference at one place in it indicates that the Sundara Siddhānta contained algebra also ; but the author has not seen it. Sudhākara *Dvivedī says that it resembles the portion on 'bījachāyā' by Bhāskara, and that the aphorism "sarupake varṇakṛtītu yatra" meaning 'has been refuted, in it'.

The Siddhānta Sundara, follows the modern Sūrya Siddhānta. Like a karaṇa work, it gives the epochal positions of planets and annual rates of motion for finding the planets' places. The epochal positions are true for Śaka 1425. The moment for which they are true is not mentioned. But the author has found from actual calculation that they have been calculated for the moment of 56 ghaṭis 39 palas after sunrise on Thursday, the 8th lunar day of the bright half of Āśvin in that year. These positions and the rate of yearly motion of the planets, completely follow the modern *Sūrya Siddhānta*. The epochal positions appear to have been given for an odd moment. But the mean longitude of the Sun in it is $6^s\ 0^\circ\ 14'\ 17''$, which shows that it is true for a moment exactly 15 ghaṭis after the mean Libra Ingress. From this, his object seems to give the positions for 15 ghaṭis after the mean Libra Ingress. A correction to planetary places has been mentioned in the chapter on mean places.

खाभ्रखाभ्राष्टभू १८०००० भिर्गतं यत्कलेस्तष्टमेतस्य यातैष्ययोल्पकं ॥
तद्रवा १ पावकैः ३ सिद्ध २४ संख्यैर्हतं दृग्यमैः २२ खाग्निभिः ३० खांककै ९०
वंन्हिभिः ३ ॥ ८३ ॥
नंद ९ विग्नायुतेना १०००० प्रभागैर्युताः सूर्यसौरावनीजाः परे वर्जिताः ॥
दृक्समत्वं ग्रहाणामनेन स्फुटं प्राह दामोदराचार्य एवं बुधः ॥ ८४ ॥

Translation :—

A correction for the modern *Sūryasiddhānta* has been mentioned before page 45) ; this is 30 times that correction ; otherwise it is the same as that one in all respects. The correction to be applied to the Sun according to the figures given on page 45 comes to 6″ only. This is negligibly small. Dāmodara's correction, as mentioned by Jñānarāja in the case of the sun, for the above mentioned year comes to 3′. This appears to be a more probable correction-figure. If the reading 'bhāgādi' given in the 7th verse of the chapter on 'Bījopanayana' in Sūryasiddhānta, be changed to 'Rāśyādi', the correction mentioned therein would exactly agree with that given by Dāmodara. The reading 'bhāgādi' seems to be the copyist's error, and one is led to infer that the correction given in the Sūrya-Siddhānta (page 45) owes its origin to Dāmodara himself. The annual correction to be applied to the sun's place, as mentioned by Dāmodara, comes to $+1/25''$. This reduces the length of the solar year by 2^{v}.-26^{pr}.-6^{ppv} (vipalas etc.) that is, the length of the year, 365^{d}-15^{gh}-31^{p}-31^{vp}.-24^{pu} becomes 365^{d}-15^{gh}-31^{p}-28^{v}-57^{pv}-54^{vpv}. The account of one Dāmodara who lived about the Śaka year 1339 has been given before, on page 125, and he must be the same as this very Dāmodara.

Jñānarāja does not appear to have mentioned the ayanāṃśas of his time. He has simply explained the term 'ayanāṃśa' as the difference between the sun's

*Sudhākara Dvivedi, teacher of Mathematics at the Sanskrit College, Vārānasī wrote a book entitled, *Gaṇaka Taraṅginī*, in Sanskrit in Śaka 1814 has been printed. See page 56 of the book. The book contains an account of astronomers.

position calculated from the shadow cast by the noon sun and that obtained from 'calculation' based on a Karaṇa work. The annual rate of equinoctial motion has been said to be 1′. He has also given the method of finding ayanāṃśa as described in the Sūrya-Siddhānta. The rate of annual motion when calculated by it comes to 54″.

Jñānarāja, after mentioning the opinion of the Śrutis and Purāṇas about the increase and decrease of the moon's digits, observes, in the chapter on the elevation of the moon's cusps :—

वेदे सुराः सूर्यकराः प्रसिद्धास्त एव यच्छंति कलाः क्रमेण ।।
सितेऽसिते ते क्रमशो हरंति ।। ६५ ।।

Translation :—

"The sun's rays themselves are known in the Vedas as Gods. They gradually add the objects to and carry them away from the moon in the bright and dark half of the month."

The Sundara-Siddhānta gives nothing new as established by observation. Some explanations of theory, however, are different from those of Bhāskara. The chapter on Yantramālā describes one new instrument. There is no harm in saying that the work Siddhānta-Sundara is on the whole beautiful as the title suggests.

Other Works

Sūrya has recorded in his commentary on Bhāskara's Bījagaṇita that Jñānarāja has, in addition to the Siddhānta, written a work, on each of the following subjects ; astrology, rhetoric and music.

Account of Descendants

An account of his descendants Ḍhuṇḍhirāja, Gaṇeśa and Sūrya has been given for each separately later on. It has been already mentioned before, that Cintāmaṇi wrote a commentary on Sundara-Siddhānta. Here the author gives an account of some of the remaining descendants on the basis of the information supplied by Kāśīnātha Śāstrī. It is not known when this family shifted from Pātharī to Bid for permanent residence. Bid is a place about 50 miles to the W.S.W. of Pātharī, and about 60 miles to the South of Daulatābād and 50 miles to the S.E. of Paiṭaṇā. Nāganātha has compiled a commentary named Narapati jayacārya. Puruṣottama has written Keśavī Prakāśa and Varṣa saṃgraha, two works devoted to astrology and written another work entitled Datta Kutūhala. He writes in the Keśavī Prakāśa that Rāmacandra was proficient in the science of astrology and that Vijñāneśvara was a scholar of logic, grammer and astronomy, and was honoured by king Bājī Rao. This Bājī Rao was the last Peśwa (Śaka 1717 to 1739). Kāśīnāha Śāstrī is still living and he is a scholar of logic, grammer and astronomy. He is the highest officer at Bid. He is very much honoured in the Hyderābad State. He has been honoured by the Śankarācārya of Hampi Virupakṣa, who conferred on him the title of Sūri Cūḍāmaṇi. He has complied a work entitled Nyāyāpota and is engaged in writing the work Śrī Devi Bhāgavat Cūrṇikā, of which he has compiled five chapters.

Sūrya (Birth Śaka 1430)

He was the son of Jñānarāja, the author of Siddhānta-Sundara. He has written a commentary on Bhāskara's 'Bija' in which he has called himself Sūryadāsa and the work, Sūrya Prakāśa. He has stated that he wrote the commentary in Śaka 1460, that is in his 31st year. From this, his birth year comes to either Śaka 1429 or 1430. This commentary contains 2500 verses. At some places he has given his name simply as "Sūrya". He has written a commentary, *Ganitāmṛta Kūpikā* on Bhāskara's Līāvatī. It belongs to Śaka 1463. The theory in it has been explained by numerical quantities, and regarding the work Lilāvatī as a poem, he has given several interpretations of some of the verses in it. This commentary contains 3500 verses. Both these works have a verse given at the end which cites the names of eight works written by him. They are :—

Lilāvatī Ṭikā, Bīja Ṭikā, Śrīpatipaddhatigaṇita, Bījagaṇita, Tājikagrantha, Kāvyadwaya, and a work on metaphysics entitled *Bodhasudhākarā.* The fourth of these, Bījagaṇita, is his own independent work. The title of the Tājika work is *Tājikālankārā.* There is a copy of the work in the Deccan College Collections. This copy also contains the above mentioned verse, though the word 'Kāvyāṣṭaka' is found there in place of 'Kāvyadwaya'. Even the information sent by Kāśinātha Śāstrī reveals that Sūrya Pandit compiled 'kāvyāṣṭaka' and the names of the 8 works are given thus. 'Padyāmṛtataranginī'; Rāmakṛṣṇa Kāvya, Śankarābharaṇa, Nṛsiṃha Campu, Vighna Mocana, Bhagavatīgita etc. The poem 'Rāmakṛṣṇa Kāvya' is well known and its verses are capable of double interpretation, one of which applies to Rāma and the other to Kṛṣṇa.

Colebrooke *writes, "He (Sūryadāsa) was the author of a complete commentary on the *Siddhānta Śiromaṇī*, and of a distinct work on Calculation, under the title of *Gaṇitamālati* and of a compilation under the name of *Siddhānta-Saṃhitā-Sār-Samuccaya*, in which he makes a mention of his commentary on the *Śiromaṇī*". These three works have either been included in the above-mentioned verse enumerating his works, or in the information sent by Kāśīnātha Śāstrī, nor have they come to the authors' notice. The Aufrecht catalogue recording the names of works written by Sūryasuri or Sūryadāsa or Sūrya, include the names of the above three works, and most of the works mentioned earlier, and also the following additional works :—

Graha Vinoda, Kavi Kalpalatā Ṭikā, a commentary on Bhagavadṛta entitled Paramārthaprapā Bhaktiśata ; vedānta Śata Śloki Ṭikā and a commentary on Amaru Śataka, named Śṛṃgāra Taranginī.

On the whole, it seems that Sūrya had been a very great scholar. He was fully justified in speaking of himself in his gaṇitāmṛtakūpikā as 'a worthy pilot on the ocean of mathematics, an expert in prosody, rhetorie and music, and can adopt in high-class literature.' In the work "Gaṇitāmṛta Kūpikā he makes the following statement about himself :—

"Ahaṃ Sūryābhidhānaḥ Kaviḥ swhpradnyāpariṇāmataḥ Lilāvatīṃ vyākhyātuṃ vihitādarosmi".

*Miscellaneous Essays, 2nd edition, Vol. II, p. 251. I have stated on page144, on the basis of Colebrooke's statement, that Sūryadāssa's commentary on Līlāvatī belongs to Śaka 1460. But that is a mistake. I got the correct information, about Sūryadāsa after that page was printed. The Śaka should be 1463.

Translation :—

"I, Sūryadāsa, have ventured to write a commentary on Līlāvati, on the strength of the intellectual power possessed by me." He further adds,

निर्भंथ्य बीजगणितार्णवमात्मयत्नात्सद्वासनामृतमवाप्रमिदं मया यत् ।।
तत्संग्रहाय गणितार्णवकूपिकेयं टीका विरच्यत इहावनिदेवतुष्टचै ।।

At the beginning of his commentary of Bīja, he remarks.

यत्पादांबुरुहप्रसादकणिकासंजातबोधादहं पाटीकुट्टकबीजतंत्रगहनाकूपारपारंगमः ।।
छंदोलंकृतिकाव्यनाटकमह (?) संगीतशास्त्रार्थवित्
तं वंदे निजतातमुत्तमगुणं श्रीज्ञानराजं गुरुं ।। २ ।।

Still, at the end he observes,

तत्सूनुः (ज्ञानराजसूनुः) सूर्यदास सुजनविधिविदां प्रीतये बीजभाष्यं ।।
चक्रे सूर्यप्रकाशं खमतिपरिचयादादितः सोपपत्ति ।। ३ ।।

It appears from this that though he acquired knowledge from his father Jñānarāja, his work was mainly the outcome of his own intellectual wealth.

ANANTA—1447

He compiled 'Anantasudhārasa', a work on the calculation of the *Pañcānga*, in Śaka 1447. It follows the *Sūryasiddhānta*. Ananta remarks in the beginning.

दुंढिविनायकचरणद्वंद्वं मुदमादधन् नत्वा ।। सूक्ष्मानंतरसाख्यं तनुते श्रीकांतजोऽनंतः ।।

From this, the name of his father appears to be Śrīkānta. The author has not seen the work himself. He has stated this from (the information given in) the Gaṇakataraṅgiṇī by Sudhākara. Sudhākara says that it was a work consisting of tables and that, Nārāyana was the author of Muhūrtamārtaṇḍa, his father's name was Ananta, and Ananta's father's name was Hari (see the account of Gangādhara, Śaka 1502, given later on) and Śrīkānta, the name of the father of this Ananta, also is an epithet of Hari, and the dates of both of them appear to agree. From this, he (Ananta) seems to have been the father of the author of Muhūrta Mārtaṇḍa. But there is a commentary, Sudhārasakaraṇacaṣaka, on Ananta's 'Sudhārasa', by Ḍhuṇḍhirāja, and according to Aufrecht's catalogue, a part of this work called *grahaṇodaya* is in the library of the Sanskrit Pāthaśālā at vārānasī.

From this it appears that this is a karaṇa work containing tables useful for Pañcānga calculation. An account of the family occurs at 2 or 3 places in the works compited by Nārāyaṇa, the author of Muhūrtamārtaṇḍa, and by Gangādhara, his son (Page 150. It is mentioned every where that Hari is the name of Ananta's father and not Śrikānta. They give much information about Ananta but nothing about his works. This leads the author to doubt if this Ananta was really the father of the author of Muhūrtamārtaṇḍa.

ḌHUṆḌHIRĀJA

From the family history given by him in his work, Jātakābharaṇa, and by his son Gaṇeśa in his work 'Tājikabhūṣaṇa', it becomes evident that he was the resident of Pārthapur (Pātharī), situated to the north of Godāvari, near Devagirī (Daulatābād). He has stated Nṛsiṃha to be his father's name. The author has, on the basis of the genealogical table sent by Kāśīnātha Śāstrī, recorded him as the son of one Nṛsiṃha whose name appears in the genealogical tree, printed on page 140 in his account of Jñānarāja. From this, Ḍhuṇḍhirāja would be the uncle of Jñānarāja, the author of the *Sundara Siddhānta*. But Ḍhuṇḍhirāja has offered salutations to the preceptor Jñānarāja at the beginning of his work *Jātakābharaṇa*. This leads one to suspect that Jñānarāja, his preceptor, might have been different from the author of Siddhānta sundara, or else, Ḍhuṇḍhirāja might have been the son of some other Nṛsiṃha of the same family. Ḍhuṇḍhirāja has written a commentary 'Sudhārasakaraṇacaṣaka', on Sudhārasa, a karaṇa work, by Ananta ; similarly, according to Aufrecht Catalogue, the works, *Grahalāghava-Udāharaṇa*, *Graha-phalopapatti*, *Pañcāngaphala*, and *Kuṇḍakalpalatā*, were compiled by him. If this Ḍhuṇḍhirāja be the same person as Ḍhuṇḍhirāja, the author of the *Jātakābharaṇa*, his date must have been later than Śaka 1447. Viśvanātha (Śaka 1551) has referred* to the *Tājikabhūṣaṇa* by Gaṇeśa, son of the author of the *Jātakābharaṇa*. It follows from this that the date of compilation of the *Jātakābharaṇa* must have been earlier than Śaka 1500**.

Ḍhuṇḍhirāja's work *Jātakābharaṇa*, is very famous and it is now printed. It appears from the *Jātakābharaṇa* that Ḍhuṇḍhirāja's uncle compiled a work on astrology. The nam e of this uncle and that of his work are not known. Gaṇeśa's work, *Tājikabhūṣaṇa*, is also well known. It is recorded in Aufrecht's Catalogue that Gaṇeśa had another work, *Gaṇita Manjarī* to his credit.

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*Viśvanātha-remarks in his commentary on the *Tājika Nīlakanṭhī* that the statement of the author of *Tājikabhūaṇa* viz. "Janmakālanalinī..........." is wrong ; and this view is correct.

**Further information was received from Kāśīnātha Śāstrī after 272 pages of the book were printed. Its summary is given below !—

"Ḍhuṇḍhirāja carried on his studies under the care of Jñānarāja himself. The Śaka years of birth and death of the descendants, beginning from Sūrya are as follows :— Sūrya 1429-1510 ; Nāganātha 1480-1537 ; Gopāla 1545-90 ; Jñānarāja, bitrh year 1595 ; Rāma's death 1731 ; Vijñāneśvara 1712-1769 ; Puruṣottama 1748-1799 ; Kāśīnātha, birth year, 1768. Nāganātha the son of Sūrya had received the title 'Raṇaśūra' from the Delhi Court. He compiled the work, entitled 'Narapatijayācārya,' Kāśīnātha Śāstrī received the title Sūricūḍāmaṇi in Śaka 1813 "Instances are found in which the uncle is younger than the nephew ; and hence it is not impossible that Ḍhuṇḍhirāja studied under the care of Jñānarāja and in that case the date of compilation of Jātakābharaṇa would come to somewhere between Śaka 1430 and 1460 and that of Tājikabhūṣaṇa Śaka 1480. Nāganātha whose name written below that of Sūrya in the genealogical table was Sūrya's son ; Gopālaand Jñānarāja are different persons, and there night have been one person each between Nāganātha and Gopāla and Gopāla and Jñānaraja (Otherwise, their date may be wrong). The author' is not quite sure that the above-mentioned Śaka years are quite reliable. But in the absence of the correct dates he has notedthem here for what they are worth. Nāganātha may have received the title of 'Raṇaśūra' in the reign of Akbar or Jehangir. There is an ancient work, entitlee Narapatijayācārya, written in Śaka 1097 and hence, I have presumed that Nāgnātha wrote a commentary on Narapatijayācārya, but it is not known if Nāganātha had actually written an independent work of the same title.

ANANTA

Ananta wrote a commentary on '*Kāmadhenu*', a work devoted to the calculation of tithi and other parts of the almanac ; and Ananta has written a commentary on it. The work, Kāmadhenu, was compiled in Śaka 1279 by Mahādeva, son of Bopadeva, a resident of Tryambaka on the bank of Godāvarī. It contains tables for calculating tithis etc. according to Brahmapakṣa and Āryapakṣa. The sons of this Ananta namely Nīlkaṇṭha and Rāma, compiled works in Śaka 1509 and 1512 respectively. From this, the date of Ananta's commentary on Kāmadhenu comes to about Śaka 1480. The Jātakapaddhati is an astrological work written by Ananta*.

FAMILY HISTORY

Rāma, the son of Ananta has recorded his family history in the conclusion of his work, *Muhūrta Cintāmaṇi*, as follows :—

आसीद्धर्मपुरे षडंगनिगमाध्येतृद्विजैर्मंडिते । ज्योतिर्वित्तिलकः फणींद्ररचिते भाष्ये कृतातिश्रमः ।।
त्रंशवृत्त तत्तज्जातकसंहितागणितकृन्मान्यो महाभूभुजां । तर्कालंकृतिवेदवाक्यविलसद्बुद्धिः
स चिंतामणिः ।। ८ ।!

ज्योतिर्विदगगवंदितांघ्रिकमलस्तत्सूनुरासीत् कृती नाम्मानंत इति प्रथामधिगतो भूमंडलाहस्करः ।।
यो रम्यां जनिपद्धतिं समकरोदुष्टाशयध्वंसिनीं ।। टीकां चोत्तमकामधेनुगणितेऽकार्षीत्सतांप्रीतये ।।
नदात्मज उधारधी बिबुधनीलकंटानुजो । गणेशपदपंकजं हृदि निधाय रामाभिधः ॥
गिरीशनगरे वरे भुजभुजेषुचंद्रैर्मिते १४२२ । शके विनिरमादिमं खलु मुहूर्तचिंतामणिं ।। १० ॥

The author is giving his genealogical table below on the basis of this account and from the history given by his descendants in their works. His gotra was Gārgya. He was a resident of Dharmapurī, in Bidarbha, in the valley of the Godāvarī. Ananta left the place for Vārānasī where he resided. His descendants also used to reside at Vārānasī.

Cintāmaṇi (Gārgya Gotra)

Ananta (Padmā his wife)

Nīlkaṇṭha (Candrikā his wife) Śaka 1509 — Rāma, (Śaka 1512, 1522)

Govinda (Gomatī his wife)
Birth Śaka 1491

Mādhava
Śaka (1555)

* The author has not seen Ananta's works but he has described his work on the basis of the accounts given by his descendants and the *Gaṇnaka Tarangiṇī* by Sudhākara.

History of Descendants

From the account given by Rāma and Nilkāntha, Cintāmaṇi appears to have been an astronomer and a great scholar. Ananta's account has already been given above.

The name of Nīlkaṇṭha's mother was Padmā. He has compiled a work entitled *Toḍarānanda*. Descriptions of this work occur in other works, from which it appears that the work contained all the three branches of astronomy, Gaṇita, Muhūrta and Horā : and even Mādhava, the grandson of Nīlkaṇṭha has supported this surmise. The author of *pīyūṣadhārā* (commentary) writes that it treats the risings and settingsof planets in the chapter Candravāravilāsa and deals with Nyūnādhimāsa (suppressed and intercalary months) in the chapter called Kālaśuddhīsaukhya. The author has seen a part of the book (No. 5088 in the Ānandāśrama) ; which contained only the section on Muhūrta. It contains a large collection of excerpts from earlier writers. The number of verses in the portion seen by him is about 1000 ; it contains a chapter on pilgrimage only and that too is incomplete. It appears, therefore, that the work must have been very voluminous. It may have received the name Toḍarānanda after Toḍarmalla, the minister of Akbar. Nīlkānṭha was a great follower of Mīmānsā and a scholar of *Sāṃkhya* Śāstra and as described by his son Govinda, was Paṇḍitendra, (the leader of Pandits) at the court of Emperor Akbar. Nilkāntha compiled a work *Samātantra*, (Varṣatantra), on Tājik which is also known as *Tāika Nīlkānṭhi*. The work is very famous and has been published along with different commentaries. Nilkāntha compiled it in Śaka 1509. Viśvanātha has written a commentary on it with examples. It belongs to Śaka 1557. The Aufrecht catalogue mentions the following additional commentaries on it :—

The Dwighaṭīkā, another by Lakṣmīpati and the third entitled the Śrīphala cardhinī by Śrī Harṣa. Other commentaries have been described below. Nīlkantha has compiled a Jātakapaddhati, which contains 60 verses. According to the author of the *Gaṇakataranginī*, the system (embodied in this work) is well known in the provine of Mithilā. According to Aufrecht Catalogue, Nīlkanṭha has compiled the following astronomical and astrological works :—

Tithi Ratnamālā ; a work on Horāry astrology entitled *Praśna Kaumudī* or Jyotiṣa Kaumudī ; Daivajña vallabhya and a commentary or Jaimini Sūtra called Subodhini. From the same catalogue it appears that Nīlkanṭha also wrote commentaries on Graha Kautuka, Graha Lāghava, Makaranda and on a Muhūrta work.

The account of Rāma will follow later. Govinda, Nīlkanṭha's son, has written Pīyūṣadhārā, a commentary on Muhūrtacintāmaṇi. It is very extensive and famous. He compiled it at Vārānasī. In that work he states that Mātṛpur, in Vidarbha, was his place of residence. Perhaps, Dharmapur itself may have Mātāpur as its second name. Govinda was born in Śaka 1491. His mother's name was Candrikā. He wrote the commentary, Pīyūṣadhārā, in Śaka 1525. He also wrote the commentary, Rasālā, on Tājika Nīlkanṭhī. It was written in Śaka 1544. The commentary, Pīyūṣadhārā, reveals great ingenuity on the part of Govinda. But while in his commentary on the 9th verse in the chapter on Saṃkrānti, he observes, "Eclipses are falsified if one follow the Sāyana system of calculation. A

lunar eclipse occurred on the Full Moon day of Vaiśākha in Śaka 1516 but it is not obtained by sāyana calculation." This shows that he did not possess a profound knowledge of mathematics. In this attempt to show that the lunar eclipse was not predictable, he calculated the sāyana place of the Moon only, but he did not understand that the occurrence of the eclipse will be evident when the place of Rāhu also is found on sāyana basis.

Govinda's son Mādhava has written on Nīlkanthī a commentary known as "Śiśubodhinī Samāvivekavṛtti." It contains examples also. It belongs to Śaka 1555 and was compiled at Vārānasī. Mādhava has stated that his father Govinda, the author of the commentary Pīyūṣadhārā, was honoured by Emperor Jehangir.

The above description will show that this family has produced a good many learned scholars.

RAGHUNĀTHA (Śaka 1484).

Subodha Manjarī, a Karaṇa work by Raghunātha may be seen in the Deccan College Library (No. 217 of 1883-4 A.D.) The epochal year of the work is Śaka 1484. It follows the Brahmapakṣa. The planets' places are calculated in it from ahargaṇa. The ayanāṃśa has been assumed to be zero in Śaka 444.

RAGHUNĀTHA (Śaka 1487).

Raghunātha, son of Soma Bhaṭṭa, wrote a karaṇa work, Maṇipradīpa, in Śaka 1487. He has remarked that "he was briefly describing the planets according to Sūrya's views (*i.e.* according to the Saura Pakṣa), after consulting all works by Bhāskarācārya." There is nothing remarkable in this work. The author has not seen it. These comments are based on the *Gaṇakataranginī* of Sudhākara.

KṚPĀRĀMA

He has written commentaries with illustrative examples on Bījagaṇita, Makaranda and yantra Cintāmaṇi. He has also written commentaries on the *Sarvārtha Cintāmaṇi*, the *Pañca Pakṣī* and the *Muhūrtatatva*, and there is also a work, *Vāstu Candrikā*, written by him. This information has been collected from the Aufrecht's catalogue. The date of Muhūrtatatva by Keśava is about Śaka 1420. So the date of Kṛpārāma must be some year later than Śaka 1420.

DINAKARA

The author has seen his two works, *Kheṭaka Siddhi* and *Candrārkī*, in the Deccan College collection (Nos. 303, and 308 of 1882-83). He remarks in the *Kheṭaka Siddhi* :—

विना द्युबृंदाशुमृदुक्रियाद्यैः श्रीत्र ह्त्रसिद्धांतसमाश्च खेटाः ॥ करोम्यहं तां गगनेचराणां सिद्धिं ॥ २ ॥

The epochal positions are given for the mean Aries Ingress of Śaka 1500. These positions and the motions (of planets) are in conformity with those

computed from Brahma Siddhānta, together with the corrections mentioned by the *Rājamṛgāṅka*. The work describes only the method of finding the true places of planets. The total number of verses (in it) is 46. It appears that the works used to be accompanied by tables ; but they were not found in the copy seen by the author. But one cannot do any calculation without such tables. The writer calls this work *Laghu Kheṭaka Siddhi* which indicates that he may have written another work called *Bṛhat Kheṭaka Siddhi*. Some verses attributed to Dinakara are given in the commentary on the *Mahādevī Sāraṇī*, but they are not found in this work. This also lends support to the surmise about the existence of a larger work. The writer has given his own account in the words.

श्रीमदगोत्रे कौशिके साग्निकोभूदु दाक्षोयं ज्ञातिमोढ़प्रसूनः ॥
जातो ग्रामे साभ्रमत्याः समीपे वारेजाख्ये विप्रवर्याश्रिते च ॥ ३१ ॥
तत्पुत्रजो दिनकरः सकलानि खेटकर्माणि वीक्ष्य सततं हि सवासनानि ॥
चक्रे शके खखतिथि १५०० प्रमिते च संवत् पंचाग्निभूपति १६३५ मिते लघुखेटसिद्धिं ॥ ३२ ॥

The *Candrārkī* consists of only 33 verses and deals only with the calculation of the true places of the sun and moon.

This work also takes Śaka 1500 as its epochal year. It appears that the work may have been accompanied by tables giving the equation of centre for finding the true place of the sun and moon ; and then these are to be used for calculating tithi and other parts. From this it appears that the *Laghu Cintāmaṇi* tables of Gaṇeśa Daivajña were not in use in Gujerat in those days.

A correction stated to be in use in Gujerat is mentioned in both the works. The same correction is found also in the *Graha Cintāmaṇi* to be described (on page 151) later, and in the commentary on the *Mahādevī Sāraṇī* at some places, it is called 'Rāmabīja'.

GAṄGĀDHARA (Śaka 1508)

Ananta
Kṛṣṇa
Hari
Ananta
Nārāyaṇa
Gaṅgādhara

In Śaka 1508 he wrote Manoramā, a commentary on Graha Lāghava. He was the son of Nārāyaṇa, the author of Muhūrta Mārtaṇḍa. The genealogical table, given in the margin, is based on the information given by both the authors. The *Muhūrta Mārtaṇḍa*, was compiled in Śaka 1493, and the author has given in it his family history. From this it is learnt that he was a Vājasaneyī Brāhmaṇa belongingto Kauśika gotra. He was a resident of Ṭāpar, a village situated to the north of the famous temple of Śiva (Ghṛṣṇeśvara) which lies to the north of Devagiri (Daulatabād), and his ancestors were originally residents of Sāsamaṇūr. There is a village, Verul, situated about 4 miles from Daulatābād, and the deity there is at present known as Ghṛṣṇeśvara. Janārdana Hari Āṭalye has published the *Muhūrta Mārtaṇḍa* along with its Marāṭhī translation. He writes in its introduction that, on enquiry at the village Ṭāpar and its neighbourhood, he came to know that the descendants of the family of his meternal uncle only are now surviving.

RĀMABHAṬA (Śaka 1512)

He has written a karaṇa work entitled Rāmavinoda. It has adopted Śaka 1512 as the epochal year, and the length of the year, the epochal positions and motions of planets, are based on the modern Sūrya Siddhānta. The corrections to be applied to planets' motions are the same as those mentioned before (page 45) Under orders of Śrī Mahārāja Rāmadāsa, a minister of Akbar, Rāma Bhaṭa compiled* the Rāmavinoda in year 35 of the Akbar era 35 (*i.e.* Śālivahana Śaka 1512). It contains 11 chapters and 280 verses. Viśvanātha has written an illustrative commentary on it. Rāma has compiled a small volume of tables devoted to the calculation of tithi's etc., containing 17 verses, which form a part of the work; and Sudhākara Dwivedī says, that people on Jaipur side compile their almanacs with the help of this work.

His well-known work Muhūrta Cintāmaṇi was written in Śaka 1522. It was compiled at Vārānasī. The author himself has written a commentary on it entitled 'Pramitākṣarā. In addition to this there is the famous commentary, Piyūṣadhārā, on it, written by his nephew Govinda. Both these commentaries have been printed.

His family history has already been given (page 147) under the account of Ananta.

ŚRĪNĀTHA (Śaka 1512)

He wrote a Karaṇa work, named *Graha Cintāmaṇi* in Śaka 1512. It describes the method of calculating planets' places from 'Varṣagaṇa'. The work appears to have been accompanied by tables. They were not found along with the copy seen (Deccan College Collection No. 304 of 1882-83). The work is of no use without them. The work neither gives any epochal positions nor any clue to ascertain the school (pakṣa) to which it belongs. The work has two chapters and even includes the section on astrology. The name of Śrīnātha's father, was Rāma** and that of his elder brother, Raghunātha.

VIṢṆU

There is a well-known village named Pātharī in Bidarbha. It has already been described on page 141. There is a village Golāgrāma, near the northern bank of the river Godāvarī and 2½ yojanas (about 20 miles) to its west. A very well-known family of scholars lived in that village. The family shifted to Vārānasī later on. It produced a number of authors and Viṣṇu was one of them.

He compiled a Karaṇa work. It has adopted Śaka 1530 as the epochal year; it belongs to Saurapakṣa. He has in addition written a commentary named *Subodhinī* on the Bṛhat *Cintāmanī by* Gaṇeśa Daivajñya, the author of the *Graha Lāghava*. It explains the theory also. The study of such commentaries proves very useful for the compilers of new works on astronomy. His brother Viśvanātha has written an 'Udāharaṇa' on his Karaṇa work. In his *Muhūrta cudāmaṇi*, Śiva informs that Viṣṇu was the 'Jagatguru' (world teacher). In

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* According to Dr. Bhāṇḍārkar (*Report on the search for Sanskrit Manuscript* 1883-84, Page 84) it was compiled in Śaka 1535; but that is an error.

**Prof. Bhāṇḍārkar remarks that this Rāma may probably be the same as Rāma, the author of Muhūrta Cintāmaṇi (Report on the search for Sanskrit Manuscript 1882-83, page 88). But the account of Rāma, the author of the *Muhūrta Cintāmaṇi*, given above, will show that it is an impossibility.

addition to this, some more account of the author will be found in the following verses by Viśvanātha.

The famous commentator Viśvanātha, and Kamalākara, the author of Siddhānta tattva were born in this very family. The following verses appear in a detailed account of his family given by Kamalākara :—

अथात्र सार्धबिरदस्र २०।३० संख्यपलांशकैरस्ति च दक्षिणस्यां ॥
गोदावरीसौम्यविभागसंस्थं दुर्गं च यद्देवगिरीति नाम्ना ॥ १ ॥
प्रसिद्धमस्मान्नृप. १६ योजनैः प्राग्याम्यांतराशास्थितपाथरी च ॥
विदर्भदेशांतरगास्ति रम्या राज्ञां पुरी तद्गनदेशमध्ये ॥ २ ॥
तस्यास्तु किंचित्परभाग एव सार्धद्वि २ ॥ तुल्यैः किल योजनैश्च ॥
गोदावरीर्वाति सदैव गंगा या गौतमप्रार्थनया प्रसिद्धा ॥ ३ ॥
अस्याः सतां सौम्यतटोपकंटे ग्रामोस्ति गोलाभिधया प्रसिद्धः ॥
तथैव याम्ये पुरुषोत्तमाख्या पुरी तयोरन्तरगा स्वयं सा ॥ ४ ॥
गोदावरीसौम्यतटोपकंठगोलाख्यसद्ग्रामसुसिद्धभूमौ ॥
विप्रो महाराष्ट्र इति प्रसिद्धो रामो भरद्वाजकुलावतंसः ॥ ७ ॥
बभूव तज्जोखिलमान्यभट्टाचार्योतिशास्त्रे निपुणः पवित्रः ॥
सदा मुदा सेवितभर्गसूनुर्दिवाकरतत्तनयो बभूव ॥ ८ ॥

Translation :—

(1) On the northern bank of Godāvarī is situated the fortified town called Devagirī, whose latitude is 20°-30′.

(2) The city of Pātharī, which is 16 yojanas from this town and in S.E. direction is the capital of Vidarbha and is situated in the middle of the country.

(3) At a place, a little West to this city and about 2½ yojanas away, is a spot on the bank of the Godāvarī, where the river Ganges is regarded to have come to stay with the request of Gautama.

(4) On the northern side of this river there is a village named 'Gol' and on the southern side is a village named Puruṣottama, the river flows between the two.

(7) There lived in the village of Gol, on the northern bank of Godāvarī, a Mahārāṣtriān Brāhmaṇa, named Rāma belonging to Bharadwāja gotra.

(8) His son, Bhaṭṭācārya became very famous as a scholar of astronomy and he (Bhaṭṭācārya) got a son, Divākara, by the favour of God Gaṇeśa whom he used to worship.

Rāma was an astronomer ; Bhaṭṭācārya was a follower of 'Mīmāṃsā and a logiciar. Divākara was a great astronomer and a disciple of Gaṇeśa Daivajñay, the author of the *Graha lāghava*. Such is the information that one can gather from the family history writter by Viśvanātha, Nṛsiṃha, Mallāri and other descendants of his family.

Divākara had five sons. Viśvar ātha has paid a fine tribute to their erudition and character in his commentary on Tājika Nīlkanṭhi. Viśvanātha himself was the your gest of the five. The description runs thus :—

दिवाकरो नाम बभूव विद्वान् दिवाकराभी गणितेषु मन्ये ॥
स्वकल्पितैर्येन निबंधवृंदैर्व्यधंजगद्दर्शितविश्वरुपं ॥ २ ॥

तस्यात्मजा: पंच समा बभूवु: पंचेंद्रकल्पा गणितागमेषु ।।
पंचानना वादिगजद्रभेदे पंचाग्निकल्पा द्विजकर्मणा च ।। ३ ।।
अजनिष्ट कृष्णनामा ज्येष्टस्तेषां कनिष्टानां ।।
विद्यानवद्यवाचां वेत्ता स स्याज्जगत्स्व्यात: ।। ४ ।।
तस्माज्यात: कनिष्टो विविधबुधगणात्स्वेष्टतां प्राप जाग्र-
ज्ज्योति:शास्त्रेण शश्वत्प्रकटितविभवो यस्य शिष्य: प्रशिष्य: ।।
विष्णुर्ज्योतिर्विदुर्वीपतिविदितगुणो भूमिदर्वीकरेंद्रो ।।
ग्रंथव्याख्यानखर्वीकृतविबुधगुरुर्गर्वहा गर्वभाजां ।। ५ ।।
आसीदासिंधुदासीकृतगणकगणग्रामणीगर्वभेत्ता ।।
नेता ग्रथांतराणां मतिगुरुरनुजस्तस्य कस्पाप्यतेजा: ।।
मल्लारिर्वादिवृंदप्रशमनविधये कोपि मल्लारिनामा ।।
व्यक्ताव्यक्तप्रवक्ता जगति विशदयत्सर्वसिद्धांतवक्ता ।। ६ ।।
तस्यानुज: केशवनामधेयो ज्योतिर्विदानंदसमुद्रचंद्र: ।।
वाणीप्रवीणान्वचनामृतेन संजीवयामास कलाविलासी ।। ७ ।।
तस्यानुज: संप्रति विश्वनाथो विष्णुप्रसादादगुणमात्रविष्णु: ।।
सर्वज्ञदैवज्ञविलाससुज्ञात् नृसिंहत: साधितसर्वविद्य: ।। ८ ।।

Summarized translation :—*

(2) Divākara came to be regarded as an authority in astronomy, and was, like the 'diwākara' (sun) who envelopes the whole universe with his rays, described the construction of the universe by compiling various astronomical works.

(3) He had five sons, who were like five Indras in the subject of astronomy, or like five lions defeating the opponents or like five sacred fires on account of their pious behaviour.

(4) He gave birth to Kṛṣṇa, the eldest of the fives who became famous because of his faultless knowledge.

(5) The next son born, was Viṣṇu, who had attained such superiority of intellect, that his disciples, along with their disciples, could defeat their opponents in discussions on astronomical topics.

(6) The next son, Mallāri, became very famous because of his knowledge of arithmetic, algebra and mensuration.

(7) His younger brother, named Keśava, was still superior in so far as he compiled siddhānta works.

(8) His younger brother Viśvanātha, who got his education from Nṛsiṃha, became a scholar of all śāstras including astrology and astronomy.

* In translating these verses, the author) has omitted the translation of various lengthy poetic epithets used for the astronomers simply for the sake of composition, since these have nothing to do with the history of astronomy.

The following verses by Kamalākara which follow those given above state the history of this family as follows :—

अस्यार्यवर्यस्य दिवाकरस्य श्रीकृष्णदैवज्ञ इति प्रसिद्धः ।। ९ ।।
तज्जस्तु सदगोलविदां वरिष्टो नृसिंहनामा गणकार्यवंद्यः ।। १० ।।
बभूव येनात्र च सौरभाष्यं शिरोमणेर्वार्तिकमुत्तमं हि ।।
स्वार्थं परार्थं च कृतंत्वपूर्वंसद्युक्तियुक्तं ग्रहगोलतत्वं ।। ११ ।।
तज्जस्तु तस्यैव कृपालवेन स्वज्येष्टसद्बंधुदिवाकराख्यात् ।।
सांवत्सरार्यादगुरुत: प्रलब्धशास्त्रावबोधो गणकार्यतुष्टचै ।। १२ ।।
दृग्गोलज्ञक्षेत्रनवीनयुक्तचा पूर्वोक्तितः श्रीकमलाकराख्यः ।।
समस्तसिद्धांतसुगोलतत्वविवेकसंज्ञं किल सौरतत्वं ।। १३ ।।
खनागपंचेंदु १५८० शकेष्वतीते सिद्धांतमार्याभिमतं समग्रं ।।
भागीरथीसौम्यतटोपकंठवाराणसीस्थो रचयांबभूव* ।। १४ ।।

Translation :—

(9 & 10) This talented Divākara had a famous son, the astronomer Śrīkṛṣṇa, who, in his turn gave birth to a son, Nṛsiṁha, who was well versed in the knowledge of the '*sphere*' and honoured by astronomers.

(10) He compiled a commentary on the Śiromaṇi, and one on the *Sūrya siddhānta* and a work explaining the sphere and motions of planets. (11 to 14) His (second) son Kamalākara who got his learning from his learned elder brother Divākara, who was his preceptor in the astrology, compiled the above mentioned works on astronomy, including the new theory of spherical areas. This work was intended to be a standard work, explaining all theories about 'gol and siddhānta and was named 'Siddhānta, tattvaviveka'. He compiled this siddhānta work in the Śaka year 1580, at Vārānasī which is situated on the northern bank of the river Bhāgirathī (Ganges).

The genealogical table prepared from this description and other information, is given below :—

Rama (A Mahārāṣtra Brāhmaṇm of Bhāradvāj gotra and Taittiriya Branch).

Bhaṭṭācārya

Divākara

Kṛṣṇa Viṣṇu Mallāri Keśava Viśvanātha

Nṛsima (Birth Śaka 1508) Śiva

Divākara (Birth Saka 1528) Kamalākara Gopinātha Ranganātha

*Siddhānta Tattvaviveka, page 407/8, printed at Vārānasī by Sudhākarā Dvivedī.

Nṛsiṃha, the son of Kṛṣṇa has written in his commentary on the Sūrya Siddhānta that Kṛṣṇa, the eldest son of Divākara compiled a work on algebra in 'Sūtra' (aphoristic) form. The Muhūrta Cūḍamaṇi, a work by his son, Śiva, and the works of Divākara, his grandson, go to show that he (Kṛṣṇa) was a seer, that he had received honours at the king's court and that he wrote works on other sciences also. According to Aufrecht Catalogue, Keśava, a son of Divākara and uncle of Nṛsiṃha, compiled a work entitled 'Jyotiṣamaṇimālā' in 1564 A.D. (Śaka 1486). He appears to be Keśava of this very family, as the name suggests, but his date does not agree with the established dates of Mallāri and Viśvanātha. A description of other persons of this family has been given further on.

Mallāri has stated that his family deity was Mallāri. In his commentary on Śiromaṇi, written in Śaka 1543, Nṛsiṃha states that Divākara died at Vārānasi. He was the direct disciple of Gaṇeśa Daivajñya, and from this it seems that he must have been in South India till about Śaka 1500. The works compiled by the members of this family after Śaka 1533 were written at Vārānasi. From this it appears that this learned family shifted to Vārānasi within 25 to 30 years after Śaka 1500. None of them seems to have received actual patronage at the Delhi Court ; they are, however, described as being honoured by kings.

MALLĀRI

Mallāri was born in the famous family described by Viṣṇu above. He has written a commentary on the *Grahalāgava.* He has described in it the date of this commentary in a strange way, thus :—

बाणो ५ नाच्छकत: कुराम ३१ विहृतान्मूलं हि मास: स युक
बाणै ५ भं च दशोनितं १० दिनमितिस्तस्या दलं स्यात्तिथि: ।।
पक्ष: स्यात्तिथिसंमितोऽखिल*युति: सप्ताब्धितिथ्युन्मिता १५४७
बालाख्यो गणको लिलेख च तदा टीका परार्थं त्विमां ।।

Translation :—The astronomer, Bāla, wrote this commentary in the Śaka year, denoted by 1547 diminished by the sum of the numbers denoting the month, the nakṣatra, the day of the week, the lunar day, and the half month. The month was the number which is the square root of "the current śaka year reduced by 5 and divided by 31" *i.e.* $\sqrt{\frac{1524-5}{31}} \doteq \sqrt{49} = 7$. The nakṣatra was equal to the month plus 5 *i.e.* 12th. The day of the week was equal to the nakṣatra reduced by 10, hence 2 or Monday ; the lunar day was the 1st and Pakṣa was the 1st"

From this it is proved that an astronomer named Bāla, wrote this commentary on Monday, the 1st lunar day of the bright half of Aśvin in Śaka 524, the nakṣatra being Uttarā. This must be the date of the commentary also, because it agrees with that of his brother Viśvanātha.

Mallāri has explained the theory of Grahalāghava in the commentary. The task of explaining the theory of a work like the *Grahalāghava* can be said to be even more difficult than that explaining the theory of a Siddhānta work. But they accompanished the work with great success.

* $1524 + 7 + 1 + 1 + 2 + 12 = 1547$

Śaka + month + tithi + pakṣa + day of the week + nakṣatra.

VIŚVANĀTHA

He was a commentator like Bhaṭotpala. He was the son of Divākara of Golāgrāma. His family history can be found from the account given by Viṣṇu. He has recorded the date of his commentary on Tājakanīlkanṭhī, as below :—

चंद्रबाण शरचंद्र १५५१ संमिते हायने नृपतिशालिवाहने ।।
मार्गशीर्षसितपंचमीतिथौ विश्वनाथविदुषा समापितं ।।

Translation :—

"This was completed by Viśvanātha on the 5th lunar day of the bright half of Mārgaśirṣa in the year 1551 of the era of king Śālviāhana."

The author has seen a number of commentaries on the Nīlkanṭhī, in many of these the above verse was missing ; it was found only in a few commentaries. It is an instance of how our people are indiffierent in the matter of specifying the dates of the compilation of their works. There is absolutely no doubt about this Śaka. It authentically becomes evident from the references at other places in the commentary. Viśvantāha has written commentaries, consisting of illustrative examples, on several works like the *Sūryasiddhānta*. For the main example in them he has adopted Śaka 1534 as the year, but has incidentally also, taken Śaka years 1530, 1532, 1542 and 1555. In the commentary on 'Pātasāraṇī', he has adopted Śaka 1553 as the year for his example. In the Keśavī-jātaka-paddhati, he has adopted for his example Śaka 1508. The birth horoscopes are cast with the help of the Jātakapaddhati. It would appear that Śaka 1508 may have been the date of birth of Viśvanātha and he appears to have compiled his works between the Śaka years 1534-56. In a line from his commentary on Grahalāghava, (already given on page 131) he calls Gaṇeśa Daivajñya his preceptor, but it is simply a matter of formality. It is like the remark by Dhanarāja, the commentator of the*Mahādevi Sāriṇī*, who in his commetary written in Śaka 1557, calls Mahādeva his preceptor, even though the *Mahādevi Sāriṇi* was compiled in Śaka 1238.

Kṛṣṇa śāstrī Goḍbole has given in the Grahalāghava three verses at the end which state that, in order to ensure agreement with observation, Viśvanātha has mentioned a correction to it 211 years after it was compiled. This means that the date of Viśvanātha comes to Śaka 1653. But it is quite evident from his family history and his works that the date of Viśvanātha, the commentator of the *Grahalāghava*, must be in the 16th century and not the 17th. The author has seen several editions of Viśvanātha's commentary on Grahalāghava, but they do not contain these three verses. Viśvanātha, referred to in them, must be a different person. Viśvanātha Davajñya Sangameśvarkara, the son of Gopāla compiled a work entitled Vratarāja at Vārānasi in śaka 1658. The above three verses may have been compiled by this Viśnanātha.

HIS WORKS

Viśvanātha has written the following commentaries containing examples:—

(1) The *Gahanārtha Prakāśikā* Ṭīkā on the Sūrya Siddhānta. In this, Viśvanātha writes, "I am elucidating the Sūrya Siddhānta, the commentary by Nṛsiṃha may be consulted for its theory". Nṛsiṃha wrote his 'Saurabhāṣya-commentary in Śaka 1533. From this it is evident that Viśvanātha wrote his

Udāharaṇa on the Sūrya Siddhānta after that date. The number of verses in it is 5000. (2) Siddhāntaśiromaṇi* (3) Karaṇa Kutūhala (4) Makaranda (5) Grahalāghava (6) Pātasāraṇī by Gaṇeśa Daivajña (7) Anantasudhārasa* (8) Rāma Vinodakaraṇa* (9) the Karaṇa work by his brother Viṣṇu* (10) Keśavī Jātakapaddhati (11) Samātantraprakāśikā on Tājaka-Nīlkaṇṭhī. This belongs to śaka 1551. The Aufrecht's Catalogue has mentioned the following additional commentaries on :—(12) Somasiddhānta (13) Tithi Cintāmaṇi (14) Candramānatantra (15) Bṛhajjātaka (16) Śrīpatipaddhati (17) Vasiṣṭhasaṃhitā (18) Bṛhatsaṃhitā.

Viśvanātha has added solved examples in the commentaries and hence those commentaries are very useful for the student. Kṛṣṇa Śāstrī Goḍbole has published a Marāṭhī edition of Grahalāghava containing solved examples, which is for the most part, a translation of the Viśvanāthī commentary.

Viśvanātha has not given any theory in his commentary ; still the fact that he had a good knowledge of the astronomical science is evident from his works. He compiled all his works at Vārānasī.

NṚSIṂHA (Birth date 1508)

He was the son of Kṛṣṇa who was the eldest son of Divākara of Golāgrāma (page 154). He was born in Śaka 1508. He was guided in his studies biy his uncles Viṣṇu and Mallāri. He wrote a commentary on the Sūrya Siddhānta entitled Saurabhāṣya in Śaka 1533. It explains the theory and contains 4200 verses. His commentary on the Siddhānta Śiromaṇī named Vāsanā Vārtika was written in Śaka 1543. It was also called Vāsanā-Kalpalatā and the number of verses in it is 5500. From both these commentaries it seems that he had a sound knowledge of astronomy. His son Divākara has written that he was very proficient in Mīmāṃsā.

ŚIVA

Born in the family described in the author's account of Viṣṇu (P. 154), Śiva was the brother of Nṛsiṃha and son of Kṛṣṇa. His birth year may have been Śaka 1510. Sudhākara states that he had written a commentary on Ananta Sudhārasa. He has compiled a muhūrta work named Muhūrta Cūḍāmaṇi. Divākara, his nephew and disciple, has rwritten in his work Jātakapaddhati, that he was a 'jagatguru' (world teacher).

According to Sudhākara, there was another Śiva, son of Rāma Daivajña, who wrote a work entitled Janmacintāmaṇi.

KṚṢṆA

He was born in a well-known family of scholars. The genealogical table below has been prepared from the family history given by the writers born in this family.

* The author has not seen these four commentaries himself. He has given the names from the *Ganakatarangiṇī*.

- Cintāmaṇi (Devarāta gotra)
  - Rāma (wife Sitā)
    - Trimalla
      - Ballāla (wife, Goji)
        - Rāma
        - Kṛṣṇa
        - Govinda
          - Nārāyaṇa
        - Ranganātha
          - Munīśvara
          - Vāsudeva
        - Mahādeva
    - Gopīrāja
  - Four other sons.

PLACE

Cintāmaṇi, a Yajurvedī Brāhmaṇa, used to reside in Dadhigrāma, a village on the Bank of Payoṣṇī in vidarbha. The position of this village has been described by Munīśvara at the end of his Marīci commentary in the line,

एलिचपुरसमदेशे तटे पयोष्ण्या शुभ दधिग्रामे ॥

meaning "In the auspicious (Village of) Dadhigrāma, situated on the bank of Payoṣṇī, in the same latitude as Ellicpur".

The *Palabhā* of Dadhigrāma, mentioned in commentary on the Keśavi Jātaka written by Nārayaṇa, son of Govinda, is 4-30, from which the latitude of the 'place would come to be 21°-15′. This is also the latitude of Ellicpur. It appears, thereofore, that Dahigāon must be a village situated to the east or west of Ellicpur, in the same latitude.*

Ballāla went to Vārānasī to reside there permanently. His descendants, as it appears from their works, continued to reside at Vārānasī. However, it appears from Nārāyaṇa's commentry on Keśava's *Jātakapaddhati* that he compiled it at Dadhigrāma.

HISTORY OF ANCESTORS

Kṛṣṇa and Munīśvara have wirtten in their works that Rāma possessed such a wonderful prophetic faculty that the King of Vidarbhas always obeyed him. The date of Rāma, as reckoned from those of Kṛṣṇa and Munīśvara appears to be about Śaka 1440. When the Bahamaṇī kingdom was split into five parts about 1500 A. D. (Śaka 1422), one of the parts was transformed into the Kingdom of Berar (Vidarbha) with Ellicpur as its capital. As Rāma is said to have been the adviser of the King of Vidarbha, he must have been residing at Ellicpur. Ballāla was a great devotee of Rudra (Śiva). Ranganātha has stated in his commentary on the Sūrya Siddhānta that Rāma, the eldest

*By the formula tan. lat.=*Palabbā*÷12, the given *palabhā* 4/30 would indicate 20°34′ (not 21°15′) as the latitude of the place. (R.V.V.)

son of Ballāla compiled a theory work to explain the 'Anantasudhākara.' This may be the same as the *Sudhārasa* of Ananta referred to on page 145. This Rāma also was a great devotee of Śiva ; and, according to the Marīci commentary, he was alive in Śaka 1557, the date of that commentary.

KṚṢṆA HIMSELF

Kṛṣṇa was the second son of Ballāla. He wrote a commentary work, Bīja navānkura, on Bhāskarācārya's 'Bījagaṇita'. The commentary has also received Bījapallava, "Kalpalatāvatāra," as additional names. Kṛṣṇa has suggested in it some new artifices of his own. The commentary has proved to be the best of the ancient commentaries and is recognized as such by learned men. In this commentary, he calls himself a disciple of Viṣṇu who was the disciple of Nṛsiṃha, the nephew of Gaṇeśa, the author of the *Grahalāghava*. It is not known if this Viṣṇu was the same as the Viṣṇu of Golāgrāma (page 154.). The dates of both of them appear to be almost the same. Kṛṣṇa has written a commentary, consisting mainly of examples, on the Jātakapaddhati of Śrīpati. He has adopted in it Śaka 1478, the birth Saka of Khānkhān, the minister, by way of example in it. There was no possibility of Khānkhān to be a minister before Śaka 1500. Ranganātha has referred to both these commentaries by Kṛṣṇa in his commentary on the Sūryasiddhānta, and he also writes there that Kṛṣṇa was held in high esteem at the court of Emperor Jehangir. Jehangir ruled from Śaka 1527 to 1549. From this, Kṛṣṇa appears to have compiled, both the commentaries during the period Śaka 1500 to 1530. He has written another work "Chādaka Nirṇaya", which had been published by Sudhākara Dvivedī. It appers from the commentary, Marīci that he had won the affection of Nuruddin, a Muslim officer, and that he was not living in Śaka 1557.

DESCENDANTS

Nārāyaṇa, son of Govinda, has written a commentary on Keśava's Jātakapaddhati, in which he has adopted Śaka 1509 for the purpose of illustrative examples. There is a work on algebra, named Nārāyaṇīya Bīja consisting of aphorisms in Ārya metre. The author of the *Gaṇaka Taraṅginī* says that it may have been compiled by Nārāyaṇa. Furthermore, this Nārāyaṇa may be identical with Nārāyaṇa, the guru of Munīśvara.

RANGANĀTHA

An account of his family has already been given while describing Kṛṣṇa's family. He wrote a commentary, Gūḍhārtha Prakāśikā, on the Sūrya Siddhānta. A detailed description of it has already been given. He has given in the commentary itself, the date of its compilation in the following verse :—

शके तत्वतिथ्युन्मिते १५२५ चैत्रमासे सिते शंभुतिथ्यां बुधेर्कोदयान्मे ।
दलाढयद्विनाराचनाडीषु ५२।३० जातौ मुनीशार्कसिद्धांतगूढप्रकाशौ ॥

Translation :—(not necessary)

Ranganātha says that his son Munīśvara, and the commentary Gūḍhārtha prakāśikā, both appeared 52½ ghaṭis after sunrise, on Wednesday, the "Śivatithi of the bright (or dark) half of Caitra in Śaka 1525 ; and it is written in the same

commentary that Kṛṣṇa was honoured by the Emperor Jehangir. Jehangir began to rule since Śaka 1527 and not before. Hence, this śaka appears doubtful. But Munīśvara's works belong to Śaka 1557, 1568 and 1572. This means that the above Śaka is not quite improbable. Ranganātha might have began writing his commentary in Śaka 1525. The '*ekādaśī*' day in the "śukla or Kṛṣṇa pakṣa" of the elapsed Śaka year 1525, could not be a Wednesday. The Śukla Caturdaśī fell on Wednesday and lasted for 10 ghaṭis. This would agree with the particulars in the quotation if *śivatithi* is taken to mean Caturdaśī. Otherwise, the Wednesday must be the 'daśamī, day in Caitra Kṛṣṇa pakṣa of Śaka 1524 which lasted for 8 ghaṭis. Hence, complete agreement is reached if 1525 be taken as the current śaka (*i.e.* elapsed Śaka 1524), the dark half as the pakṣa, and Ekādaśı as the Śivatithi. In short, Ranganātha was alive in Śaka 1525, but not in Śaka 1557, as is apparent from the Marīci commentary.

His commentary on the Sūrya Siddhānta shows that Ranganātha had a sound knowledge of astronomy, particularly that of Bhāskara's Siddhānta. He has explained the theory, throughout the commentary. It also appears from the commentary that he taught students with the help of astronomical instruments, like the celestial globe, which he had constructed himself. He wrote the commentary at Vārānasī.

GRAHA PRABODHA, Śaka 1541

This is a Karaṇa work, its epochal year being Śaka 1541. It consists of 38 verses in all, and they deal with only the question of the true places of planets. The treatment of this subject, the method of calculating ahargaṇa, eleven years' cycle, etc. are all on the lines of the *Grahalāghava*. The author writes in the colophon :

आसीत् गार्य (? ग्यं) कुलैकभूषणमणिर्विद्वज्जनानंदकृत
शिष्याज्ञानतमोनिवारणरविर्भुमीपतिप्रार्थितः ।।
ज्योतिःशास्त्रमहाभिमानमहिमास्पष्टीकृतत्रह्मधी-
धैर्योदार्यनिधिस्तुकेश्वर इति ख्यातो महीमंडले ।। ३६ ।।
तदात्मजस्तच्चरणैकमक्तिस्तद्वत्प्रसिद्धः शिवनामधेयः ।।
तदंगजो दृग्गणितानुसारे ग्रहप्रवोधं व्यतनोच्च नागः ।। ३७ ।।

Translation :—

(36) There was a Brāhmaṇa, named Tukeśvara, who was an ornament for the Gāryya, (Gārgya?) family, who gave joy to learned men, who was the 'sun' competent to remove the darkness of ignorance among his pupils, who was honoured by the king, who was very famous in the world as one who explains the astronomical theory and one who was courageous and broadminded.

(37) His son, named Śiva, who was devoted to him, was equally famous. The latter's son, Nāga, compiled this work on planetary calculation, agreeing with observation.

It appears that the author's name was Nāgeśa, his father's name was Śiva and that of his grandfather, Tukeśvara. It is doubtful how far his description of Śiva and Tukeśvara was true ; but so far as his claim to having compiled a work agreeing with observation goes, the work is hopeless. He has not

mentioned his place of residence. But the parts of A. D. (ascensional difference) correspond to a place having its palabhā equal to $4\frac{1}{2}$. The work neither gives any eopchal position 'norcakra-dhruvaka's (i.e. explements of the motion in a cycle). These may have been included in separate tables. The copies which the author happened to see (No. 422 of 1881-82 in the Deccan College collection and No. 2619 of the Ānandāśrama collection) did not contain any table.

Nāganātha's disciple, Yādava, wrote on 'Udāharaṇa' type of commentary on this work, adopting śaka 1585 for the illustrative example.

MUNĪŚVARA

WORKS

He was the son of Ranganātha, the author of Gūḍhārtha prakāśikā. The date of the commentary *viz.* Śaka 1525, is the date of his birth :—

The following three works by him are famous :—(1) A commentary on Bhāskarācārya's Līlāvatī, entitled "Nisṛṣṭārtha Dūtī Līlāvatī Vivṛti", (2) The Marīci commentary on the Chapters on Gaṇita and Gola from (Śiromaṇi) and (3) an independent Siddhānta work on astronomy known as Siddhānta Sārvabhauma. It is written in Gaṇakataranginī, that 'Pāṭisāra, is an additional work credited to his name. It seems that it may be an independant work on elementary arithmetic. He has mentioned at the end the date of the completion of the first half of the Marīci commentary in a queer chronogram :

शको भू १युतो नंदभू १६ हृत्फलस्य निरेकस्य मूलं निरेकं भवेद्भं ।
तदर्धं भवेन्मास इंदू १ नितोऽयं तिथिर्द्व २ निता पक्षवारौ भवेत ॥ १२ ॥
नक्षत्रवारतिथिपक्षयुतिश्च योगो विश्वै १३ र्युताखिलथुतिः पदमभ्रवेदाः ४० ।
अस्या यदात्र परिपूर्तिमितो मरीचिः श्रीवासुदेवगणकाग्रजनिर्मितोयं ॥ १३ ॥

Translation :—

The first part of the Marīci commentary which was begun by Munīśvara, the elder brother of Vāsudeo, was completed on the date indicated by the following mathematical formulae :—

(i) the nakṣatra number is to be obtained as follows :—

the Śaka $+1=1557+1=1558$

$1558\div19=82$; $82-1=81$; $\sqrt{81}=9$

$9-1=8$th *i.e. Puṣya*

(ii) The month would be the nakṣatra number divided by 2 *i.e.* 4th viz. Āṣāḍha.

(iii) The tithi is given by the month number diminished by 1 *i.e.* the third *viz. tṛtīyā.*

(iv) The pakṣa and vāra both to be obtained by diminishing the tithi number by 2 *i.e.* 1 viz. Śuklapakṣa and Sunday.

(v) The yoga to be indicated by the sum of numbers, denoting the nakṣatra, vāra, tithi, and pakṣa *i.e.* $8+1+3+1=13$th. (vyāghāta).

The sum of all these numbers (8+1+3+1+13) i.e. 26 increased by 13 and multiplied by 40 would give the year (=1560) of completion of the work.

These verses show that the commentary (first half) was completed on Sunday, the 3rd lunar day of the bright half of Āṣāḍha in Śaka 1557, the nakṣatra being Puṣya and yoga being 'Vyāghāta'. The latter half was completed in Śaka 1560.

Sudhākara says that the Siddhānta-sārvabhauma was completed in Śaka 1568, and the author's own commentary on it was completed in Śaka 1572. The Marīci commentary is a voluminous work and the number of verses in it being 25000. It contains a very large collection of quotations from ancient authors. The commentary on Līlāvatī contains 7000 verses and has won recognition from scholars. The commentary on the first half of the Sārvabhauma siddhānta contains 8000 verses. It is seen at several places in his works that he was a staunch admirer of Bhāskarācārya. The length of the year, the number of revolutions of planets and other measures adopted in the Sārvabhauma-Siddhānta are the same as in the Sūrya -Siddhānta.

Munīśvara was also known by another name, Viśvarupa. He writes in his commentary, Marīci, that he obtained knowledge through the favour of Kārtikswāmī. He states that, Kṛṣṇa's disciple Nārāyaṇa was his guru. Both of them probably belonged to the same family. His works show that he may have obtained the patronage of Emperor Śāhājahān. In his Sārvabhauma Siddhānta, he has recorded the year of the Hijrī era and the date and time of the coronation of Emperor Śāhājahān, and also the horoscope of the moment. From this we come to know that Śāhājahān was crowned on Monday, the 4th February, 1628 A. D., the 10th lunar day of Māgha Śukla, of Śaka 1549, (the year 1037 according to Hijrī era) at 3 ghaṭis after sunrise.

DIVĀKARA (Birth śaka 1528)

He was the son of Nṛsiṃha, a scholar from the learned family of Golāgrāma (see page 154). He was born in Śaka year 1528. He received all his education from his uncle Śiva. At the age of 19 in Śaka 1547, he compiled a *jātaka* work named, *jātakamārgapadma*, which is also known as 'Padma-Jātaka'. In Śaka 1548, he wrote a commentary, named *Prauḍha-manoramā*, on Keśava's *Jātaka-paddhati*. He similarly compiled in Śaka 1549, a commentary on his own 'Jātaka' named 'Gaṇitatattva-Cintāmaṇi, with examples.

There is a commentary (with examples) known as Makaranda-vivaraṇa on Makaranda, a work intended to be helpful in Pancāṅga calculation.

His works show that he was proficient in grammar, logic, poetry and literature.

The author has seen the work, Makaranda Vivaraṇa. The remaining account has been given from the information contained in the *Gaṇakataraṅgiṇī*. His brother Kamalākara received his training from him.

THE SIDDHĀNTATATTVA VIVEKA OF KAMALĀKARA

Siddhānta tattva-viveka is a siddhānta work by Kamalākara. Kamalākara's family history has already been given in the account of Viṣṇu (Page 154). His birth date may be about Śaka 1530. The work Tattva-viveka was compiled at Vārānasī in Śaka 1580. It follows the modern *Sūrya Siddhānta* most faithfully. Kamalākara's pride in the Sūryasiddānta had reached such a stage that he felt

that whatever was not found in the *Sūryasiddhānta* was false, and even if the same method in the *Sūryasiddhānta* were crude, while that in another siddhānta more accurate, he would still regard the latter as faulty. Thus, for instance, the correction of *udayāntara* was discovered by Bhāskarācārya, but Kamalākara regarded it as erroneous since it was not given in the *Sūrya Siddhānta*. He likewise attempted to prove that the correct method of finding the length of the circumference of a circle was the one given in the *Sūrya Siddhānta, viz.* to multiply the square of the diameter by 10 and to extract the square root of the product, even though the method given by Bhāskarācārya is really more accurate. It is needless to say that he has adopted all things like the numbers of revolutions and other elements, from the Sūrya Siddhānta and has even borrowed some verses exactly word by word. This work contains 13 chapters on the following subjects :—mean places, true places, three problems, discs shadow, elevation of moon's cusps, rising and setting, possibility of eclipses, lunar eclipse, solar eclipse, conjunction of plantes with stars, Mahāpāta and problems. All these subjects comprise 3024 verses in difierent meters. They are intersperced with prose passages and he has added a chapter named "Śeṣa vāsanā" in which he has given the theory of those subjects in the body of the book which was not given at the proper place. This work has been recently published by Sudhākara Dvivedī at Vārānasī Series.

Although the great drawback of Kamalākara has been pointed out above, his works contain many new things not to be found in the earlier works. They are :—He has stated that the place of the pole star does not remain fixed owing to the precession of the equinoxes. Similarly, that the pole star which we see at present is not situated exactly at the pole (of the equator) and its place is found to have changed when observed early at night and late in the latter part of the night. He says that it is the view of the Greeks that the major part of the earth's surface is under water and only a minor part outside it. The distance, in degrees, of a place from any meridian, in the east-west direction, which is now known as longitude, was termed by him as *Tulāṃśa* and he has given a list of latitudes and longitudes of 20 cities as below on the assumption that Khāladātta, a city on the equator, was on the Prime Meridian :—

Place	*Latitude*		*Tulāṃśa*		*Place*	*Latitude*		*Tulāṃśa*	
	°	′	°	′		°	′	°	′
Kabul	34	40	104	0	Ahmedabad	23	0	108	20
Khambayat	22	20	109	20	Burhanpur	21	0	111	0
Ujjayini	22	1	112	0	Lahore	31	50	109	20
Indraprastha	28	13	114	18	Argalapur	26	35	115	0
Somanath	22	35	106	0	Vijapur	17	20	118	0
Varanasi	26	55	117	20	Golkonda	18	4	114	19
Lucknow	26	30	114	13	Ajmer	26	5	111	5
Devagiri	20	30	111	0	Multan	29	40	107	35
Kanauj	26	35	115	0	Mandava	27	0	121	0
Kashmir	35	0	108	0	Samarkand	39	40	99	0

He has described in detail, the method of taking observations by the quadrant "instrument" and has discussed different new subjects in the chapter on "three problems" and "eclipses". He has also mentioned that at the time of the solar eclipse, an observer on the moon's disc will be able to see the earth engulfed in the shadow. He remarks that the Greeks had observed the transit of Venus across the Sun's disc. The causes of the clouds, hailstorm, earthquake, and the falling of meteors, have been explained by him. They are not wholly true, they are at least not based on superstition and in the truth. His works show some new methods related to the study on arithmetic, geometry, mensuration and trigonometry. Other siddhāntas, assume 3438 units as the radius of the earth, and give values of the sines of angles at intervalsof $3\frac{3}{4}°$. He has assumed 60 units as the value for the radius of the earth and given values for the sines of each degree, which are very convenient. A table has been given for finding the right ascension of a planet from its longitude. Other Siddhāntas give neither this table nor the method ; these are given only in Keropant's work. In short, his work has many features. It is, however, very difficult to find out how many of them he can claim as his own. It is a matter of regret that original ideas appearing in his work were not further developed.

That his brother Divākara, was his guru, has already been mentioned above while citing the verses from his work. Kamalākara was bitterly opposed to Munīśvara, the author of the *Sārvabhauma-Siddhānta*. They were contemporaries. One wonders whether it was due to jealousy that he began to hate Munīśvara and consequently also Bhāskara's works. Ranganātha, Kamalākara's youngest brother, wrote *Bhangīvibhangī*, in order to refute Munīśvara's 'Bhangī', the method of finding the true places of planets. Munīśvara, in his turn, made a counter attack (*Gaṇakataranginī* page 92.)

RANGANĀTHA

He was born in the famous family of scholars at Golāgrāma (see genealogical table on page 154). His birth year may be about 1534. He wrote the '*Mitabhāṣiṇī*', a commentary on the Siddhānta śiromaṇi. Sudhākara writes that he had compiled an independent work, named Siddhānta Cūḍamaṇi. It has 12 chapters and contains 400 verses. It follows the *Sūryasiddhānta*. Ranganātha has mentioned the date of its compilation as follows :—

मासानां कृतिरब्धि ४ हृदयुतिरसौ खाब्जैर्विहीना तिथि
वर्णै ५ हृद्दद्वि २ हतोडुवासरमितिर्वारांग ६ भामात्पदं ॥
पक्ष: सर्वयुति: शको द्विखदिनै १५०२ र्युक्ता ।

Translation :—

Calculation based on the above data shows that this work was completed on Friday (6), the full moon (15) day of Pauṣa* (10), Śaka 1565**, the nakṣatra and the yoga on that day being Ārdrā (6) and Brahma (25) respectively.

* Sudhākara has arrived at Śaka 1562 as the date referred to in this verse ; but it is an error due to oversight. The third nakṣatra that he mentions was not possible on the fullmoon day of Pauṣa in that Śaka year. The nakṣatra happens to be the sixth ; and taking that into account, the sum would not come to 1562.

** The month seems to have been puzzled out by trial and error as the original verse does not contain any clue to its name or number. Pt. Sudhākara also remarks that number 10 has to be presumed here as the number of the month because it fits the case completely. (R. V. V)

SIDDHĀNTARĀJA

BY

NITYĀNANDA (Śaka 1561)

BRIEF ACCOUNT

Nityānanda compiled the work 'Sarva Siddhāntarāja' in the year Vikram Samvat 1696 i.e. Śaka 1561. He was a resident of *Indrapurī* near Kurukṣetra. His gotra was Mudgala, he belonged to the Gauḍa clan and was brought up in the Dulīnahaṭṭa tradition of teaching. According to Sudhākara, Dulīnahaṭṭa was his traditional native place. The names of his ancestors, from his father upwards, were Devadatta, Nārāyaṇa, Lakṣmaṇa and Icchā respectively.

Description of works. Their Special Features

The work 'Siddhāntarāja', is divided into two parts—Gaṇitādhyāya and Golādhyāya. The first part contains 9 chapters and deals with the following subjects : Mīmāṃsā (Rationale), mean places, true places, three problems, lunar eclipse, solar eclipse, elevation of moon's cusps, conjunction of planets with stars and shadow. The second part, Golādhyāya, contains chapters on the universe, the celestial sphere and instruments. The special feature of this work, which distinguishes it from all other Siddhānta works described so far, is that it follows the SĀYANA system. He has fully discussed in the first chapter on 'Mīmāṃsā' (Rationale) how the *Sāyana* system is the supreme system and how it is recognized as such by Gods and Ṛṣis. The numbers of revolutions and other elements of planets etc., are as follows :—

Kalpa 4,32,00,00,000 years.

The revolutions etc. in this period are :—

Sun	432,000,0000	Saturn	146835981
Sun's Apogee	171945	Sāvaṇa days	1577847748101
Moon	57750968965	Solar months	51840000000
Moon's apogee	488327103	Intercalary months	1590968965
Mars	2296968639	Lunar months	53430968965
Mercury	17939534114	Lunar days	1602929068950
Jupiter	364356698	Suppressed tithis	25081320849
Venus	7022180538		

Number of divine years spent over creation from the beginning of Kalpa..........90410.

Number of solar days in a year 365.24253428

=365 days—14-33-7.40448

the tropical year =365 days—14-31-53.42 (By accurate modern methods).

It can be easily noted that there is considerable difference between the above figures and those given in any of the siddhāntas described before. The number of days in a Kalpa and the consequent length of the year deduced from it are less than those of others, and the numbers showing revolutions

are greater than theirs'. The number in the case of Venus is smaller, which apears to be due to some error.

The corrections to be applied to planets have been mentioned in the following verses :—

सृष्टयादितो गतसमा खयुगांगनागै ४ (?) ६४० स्तष्टा गतैष्यत इहाब्दचयोऽल्पको यः
ग्राह्यः स एव विबुधैर्ग्रहबीजसिध्यै ॥
बीजाब्दास्त्रयगर्सिधुभि : ४७३० क्षितिभुजै २१० रष्टाब्धिभि ४८० दोंरसै : ६२०
पंचांगै ६५०..४९० रूपाभ्रचंद्रै: १०१० क्रमात् ॥
भुविश्वै १३१० दंशसंगुणैश्च विहृता लब्धं कलाद्यं वियुक्
सूर्यादिग्द्युचरेषु युक्तमथ तच्चंद्रोच्चपाताख्यया ॥
सूर्योच्चे पंच लिप्ताः सदा स्वं ॥

The author remarks at the very beginning,—

दृष्टा रोमकसिद्धांतं सौरं च ब्रह्मगुप्तकं ॥ पृथक् स्पष्टान् ग्रहान् ज्ञात्वा सिद्धांतं
निर्ममे स्फुटं ॥ १४ ॥

"After studying the Romaka, Saura, and Brahma Siddhāntas, and after calculating places of planets, the writer compiled this accurate Siddhānta."

It is not known which Romaka Siddhānta is meant here. The differences in the measures will show that it can neither be the *Romaka Siddhānta* of the *Pañcasiddhāntikā* group nor that of *Ptolemy*. The Samrāt-Siddhānta (Śaka 1561) also refers to Romaka Siddhānta. The author has no means at present to ascertain what Siddhānta it was or whether it was the same as the one seen by Nityānanda. The author of the work seems to have taken observations himself. There might have been Muslim astronomers at the Delhi Court in his time, and they might have had possessed some works on Muslim astronomy in their possession. A reference to some such works occurs in the Siddhāntsamrāt. Nityānanda might have seen those works also.

The author happened to see a copy of this work with the late Rao Saheb Viśwanāth Nārāyan Mandlīk. The copy had been made from a work belonging to a learned scholar at *Jaipur*. It appears that the siddhanta is well known in those parts. It is not known, however, if the work was ever made use of in the actual calculation of almanacs.

KṚṢṆA, Śaka 1575

There is a karaṇa work entitled Karaṇa Kaustubha, written in Śaka 1575. It was compiled by Kṛṣṇa, an astronomer of Kāśyapagotra and a son of one Mahādeo. It has not been mentioned what Siddhānta it follows. But the motions of planets and the epochal positions agree with those calculated from the Graha Kautuka and the Graha Lāghava, with slight modifications.

The author has made a salutation to KEŚAVA, the author of Graha Kautuka. He says in the beginning,

प्रकुरु तत्करणं ग्रहसिद्धये सुगमदृग्गणितैक्यविधायि यत्
इति नृपेंद्रशिवाभिधनोदितः प्रकुरुते कृतिकृष्णविधिज्ञराट् ॥

"Being ordered by King Śivāji to compile such a Karaṇa work as would enable astronomers to obtain figures agreeing with observarion, Kṛṣṇa, the King of astronomers has begun to compile this Karaṇa work."

This shows that he compiled the work with the help of the two works mentioned above and his own observations. Śiva, referred to by the author, is king ŚIVĀJĪ, the founder of the Marāṭhā kingdom. There is no doubt that, in Saka 1575 i.e. in 1653 A.D. the author of the work was engaged in making preparations for the writing of the work and for taking observations. Śivājī was 26 years old then, and was actually absorbed in the work of founding the kingdom. It is very significant that even in the midst of the turmoil, he instructed the author to compile a work which would give results agreeing with observation.

The following line of the author,

कृष्णः कोंकणसत्तटाकनगरे देशस्थवर्यो वसन् ॥

shows that he was a Deśastha Brāhmaṇa residing in the *Māwalā* territory near the Sahyādri ranges.

The mean places of planets are to be calculated from varṣagaṇa according to this karaṇa work. The ayanāṃśa is assumed to be zero in Śaka 450 and the annual motion 60″. Unlike the author of the *Grahalāghava*, this author has taken the help of sines and chords. This very writer compiled a very voluminuous work entitled *Tantraratna* and this work, he says, was only a part of it. The *Tantraratna* has not come to the author's notice.

PAÑCĀNGAKAUTUKA

BY

RATNAKANṬHA, (Śaka 1580)

This is a work cortaining tables, helpful in easily calculating necessary figures for the almanac. The epochal year in it is Śaka 1580. It has been compiled on the times of the Khaṇḍakhādya. The name of the author is *Ratna Kanṭha*. He was born in Śaka 1546. His father's name was Śankara. He compiled this work for his son, Śivakantha. The writer claims that the figures for the whole almanac can be compiled in two days only from this work. It has aready been observed (page 89) that he was probably a resident of *Kashmir*.

This work gives tables for calculating the ending moments of Tithis etc. from the positions of the Sun and Moon, and the values of the *bhogya* (unexpired) parts of tithis and other items. This work can be used for finding tithis etc., when the true places and motions of the sun and moon are first found ; it evidently entails greater labour than the work Tithi Cintāmaṇi.

VĀRṢIKA TANTRA

BY

VIDDAṆA

A work of this name was found at Sholapur for the first time. It has adopted the beginning of Kaliyuga as its epoch for calculation work, and that is why it is called a *tantra*. This *tantra* was compiled by VIDDAṆA,

the son of Mallaya of Kauṇḍinya gotra. No mention has been made of the date of the work or that of its author. There is a commentary on it written about Śaka 1634. (This Śaka has been taken for an example in it). The commentator has not disclosed his name ; but his place of residence, according to the commentary, was *Baṅkāpur*. The *palabhā* of Baṅkāpur has been mentioned as 3-18 (hence the latitude would be about 15° 25′), and the longitude as about 13 yojanas (1°) west of Kārtika mountains. From this, the place appears to be situated in the *Dharwar* district. This fact and the writer's name would lead one to infer that this work had been in use in *Karṇātaka*, and the date of its compilation was earlier than Śaka 1600 ; it may have been even more ancient. It contains a verse from the *Grahalāghava*. It is not known whether the author of the *Grahalāghava* has taken it from this work or the author of this work has borrowed it from the *Grahalāghava*.

The length of the year and the revolutions of planets have beer taken from the modern *Sūrya Siddhānta*, and a correction has been mentioned for them. The correction for Mercury, as mentioned by Makaranda, is negative, while that given in this work is positive. Simiarly the Makaranda does not at all mention any correction for Mars, while this work gives plus $2\frac{2}{3}$ revolutions ; all other corrections are the same as those given in Makaranda.

From the list of corrections, this work does not appear to be older than Śaka 1400. The Aufrecht Catalogue mentions another work *Grahaṇa Mukura* by Viddaṇa.

PHATTEŚĀHA PRAKĀŚA

By

JAṬĀDHARA, Śaka 1626.

This is a Karaṇa work. The epochal year of this work is Śaka 1626 which was the 48th year of the reign of king Phatte Śāha of the Candra dynasty at Badri Kedar, near Śrīnagar. Its author is JAṬĀDHARA by name. His father's name was Vanamāli, that of his grand father was Dūrgāmiśra and that of his great-grand-father, Uddhava. His gotra was Garga. Jaṭādhara was a resident of Sarhind*.

DĀDABHAṬA

The *Kiraṇāvali*, a commentary on the *Sūrya Siddhānta*, was written by DĀDĀBHAṬA or DĀDĀBHĀĪ, a Citpavan Brāhmaṇa, in Śaka 1641. His father's name was Mādhava and surname Gaoṅkar. A reference to this commentary has already been made in the course of the authors comments on the *Sūrya Siddhānta*.

ACCOUNT OF FAMILY

According to Aufrecht Catalogue Mādhava had written a work entitled *Sāmudrika Cintāmaṇi*. Nārāyaṇa, Dādābhaṭa's son, has written in the colophon of his Tājakasudhānidhi, that MĀDHAVA was "in the service of Śrī Īśa in the Pashupatinagar ", from which he appears to have been staying at

*Prof. Bhāṇḍārkar's *Report on the Search for Sanskrit Manuscripts*, 1883-84, p. 84

Vārānasī. Mādhava had two sons, of whom Dādābhaṭa was the elder. Dādābhaṭa had two sons, of whom NĀRĀYAṆA was the younger. Nārāyaṇa compiled the following works :—

(1) Horāsārasudhānidhi (2) Narajātakavyākhyā (3) A ' Praśna ' work entitled Gaṇakapriya (4) A 'Śakuna ' work, named Svarasāgara (5) Tājaka-sudhānidhi. The date of all these works appears to be about Śaka 1660.

JAYASIṂHA

Jayasiṃha was a unique personality so far as the science of Indian astronomy is concerned. Coperinicus was born in Europe about the same time as KEŚAVA Daivajñya and Gaṇeśa Daivajñya, the two research-minded astronomers, were flourishing in our country, and the condition of astronomy both here and abroad could be said to have been similar till that age. But a great transformation took place in the condition of astronomy in Europe from COPERNICUS onwards. One may safely say that the science has now attained the acme of knowledge so far as the motions and positions of planets are concerned. It is true that the discovery of telescope and the needs of navigation were particularly responsible for this remarkable progress; still, it must be admitted that unlike Europe, our country failed to produce a galaxy of talented and diligent scholars capable of bringing about a similar advance of knowledge. It is found, only JAYASIṂHA in our country could be named as the solitary exception, comparable with the European scholars of his time.

Jayasiṃha was a king in Rajputana. He ascended the throne at Ambher in Vikram Saṃvat 1750 (Śaka 1615, i.e. 1693 A.D.). Later on, he built the present city of Jaipur and made it his capital. In his work, Siddhārtasamrāt, he has been styled " Matsya deśādhipati ". He set himself the task of compiling a work, after taking observations wih newly built instruments, set up in newly built observatories, because no existing Hindu, Muslim, or European works could give results agreeing with observation ; and accordingly he accomplished his task with success . He established observatories at *Jaipur*, *Indraprastha* *(Delhi), *ujjayinī*, Vārānasī and Mathurā. He got built very big, immovable instruments, made of mortar and stone, huge in size and very useful for observation, because, he found that metallic instruments are very small in size and wear out easily. Of these, the Jaiprakāśa, Yantrasamrāt, Bhittiyantra, Vṛttaṣṣthāṃśa etc. were newly devised by him ; and after engaging a staff of competent astronomers as observers for seven or eight years, he compiled a work entitled *viz.* 'Muhammad ' in Arabic and Siddhānta Samrāt in Sanskrit, on the basis of the records of observations taken. At that time, MUHAMMAD ŚĀH was the Emperor of Delhi and the first work was named after him. It appears that it was also called ' Mijasti '. This work belongs to the year 1141 of Hijrī era (i.e. Śaka 1650). He got the Siddhāntasamrāt compiled by a scholar, JAGANNĀTHA, about Śaka 1653 (i.e. 1731 A.D.). It is mainly a translation of the work, Mijasti. It consists of 13 chapters, contaning 141 articles and a study of 196 propositions (Kṣetras). The work records the observations taken in the year 1650-51-52 ; and the elements such as planteary motions have been determined, after comparing his own observations with those of ULUGH BEG and other ancient observers.

*The latitude of Indraprastha has been given as 28°39′ which tallies with the presen day estimate.

The Siddhāntasamrāt could not be obtained in its complete form in this province. The Ānandāśrama possesses a copy of the book prepared from the incomplete work in the possession of the Rājajyotiṣi (palace Astrologer) of Kolhapur . It contains two chapters in the beginning which describe, by way of introduction, the earth and the celestial sphere. The first chapter contains 14 articles and a study of 16 propositions (Kṣetras), and the second, 13 articles with 25 theorems. The book contains, in addition, a study of instruments and problems in geometry and trigonometry, three problems and mean & true places. The " spaṣṭādhyāya " is incomplete, and this portion contains a study of 67 propositions. All these together make about 5500 verses. From this it appears that the complete work may have consisted of about 10000 verses. Sudhākara says that according to a legend, the number was about 50000; but it is an impossibility. Moreover, Sudhākara too has not seen the entire work.

If a description of the observatories built by Jayasiṃha, and of the observations taken, and the items of original information gleaned from these, be attempted, it would take a small volume. It is enough to state here, however, that *Jayasiṃha ensured a higher degree of accuracy* in the calculation of planetary positions and motions than that achieved in Europe in those days. This reflects great credit on him as well as this country. The length of the year adopted in this work is tropical and the rate of annual precession about 51″.4. The planetary places obtained from the work appear to be sāyana. We are instructed to take the nirayaṇa places obtained by applying the ayanāṃśa-correction. The numbers of revolutions and other elements also appear to have been given as in the Sūrya Siddhānta along with corrections to be applied to them.

It is not that the work in Arabic might have been entirely compiled by Jayasiṃha himself. He had many scholars under his patronage and he might have got it compiled by them. The Siddhānta Samrāt which is for the most part a translation of the Arabic work was compiled by Jagannātha. Nevertheless, Jayasiṃha was himself a good observer, a mathematician and an astronomer. The works mention the fact that some of the subjects were explained by him in quite a new way ; and the idea of first taking observations and then compiling a work that would give results in conformity with observations was first originated by him. He had engaged competent artisans and scholars knowing one or both the languages, Sanskrit and Arabic. He had sent astronomers even to foreign lands to take observations. It is obvious that the observation work has to be carried on at several places and by several persons working in co-operation.

The Siddhānta Samrāt describes the instruments newly designed by Jayasiṃha. A description of his observatories and instruments has been given later on in the chapter on 'Observations'.

The *Siddhānta Samrāt* refers not only to ancient works in Sanskrit but to a work compiled by ULUGH BEG, grandson of Tamerlane in the Hijrī year 841 (i.e. Śaka 1359). It refers also to a work compiled by *Boosanassar*, which seems to have been compiled 619 years before that of Jayasiṃha. This figure may be indicating years of Hijrī era. It refers to the *Romakasiddhānta* and to the Yavana (Arab) astronomers, *Batalmajuṣa* and *Awarakhas*.

Jagannātha translated in Śaka 1641, 15 books of Euclid's geometry in to Sanskrit, under orders of Jayasiṃha. It is called ' Rekhā-gaṇita'. It is well known in Jaipur province. There is a copy of this book in the Ānandāśrama library (Book No. 3693), Poona. It does not mention Euclid's name. It is said to have been prepared with the help of works compiled by Ṛṣis ; there is, however, no doubt that it was compiled with the help of Euclid's work. It may have been compiled from some Arabic work which did not make any mention of the original writer, or else which contained some words suggestive of the " apauruṣeya " (divine) nature of the work and a similar remark might have found its way into the Sanskrit work also.

Sudhākara writes that Jayasiṃha offered some villages to Jagannātha by way of reward and they are still in the possession of his descendants.

Jayasiṃha got another work entitled ' Kaṭar ', compiled by ' *Navanāsukhopādhyāya* '. It is an independant work different from Euclid though compiled on the same lines. It conains three chapters which respectively consist of 22, 23 (or 22) and 14, i.e. 58 or 59 theorems in all. The first two chapters deal with theorems about circles on spheres. This book was originaly written by ' *Sāvajūsayūsa* ' in the Greek language. It was then translated into Arabic under the orders of Abul Accās AHMED. There is a commentary on it compiled by NASIR. It has been stated in the work that it was translated from Arabic into Sanskrit.

The enterprises of Jayasiṃha were not continued further. No one makes any use of his observatories and now they are mostly in a dilapidated condition. Jayasiṃha's work, Siddhānta Samrāṭ also does not appear to have come into use ; nor have almanacs been rectified therefrom. The length of the year is still the same as before. And the same works which guided the almanac-makers before the time of Jayasiṃha continue to hold the field to this day. The fact that Jayasiṃha's works were not used even in Rajputana, is really very deplorable and thought-provoking.

VAIṢṆAVA KARAṆA

BY

ŚAṄKARA, Śaka 1688

Śaṅkara belonged to Vasiṣṭha gotra and was a resident of the region around Raivatakā hill (near Dwarka). The names of his ancestors, from his father upwards were Śuka, Dhaneśvara, Rāma and Harihara. He compiled a Karaṇa work entitled *Vaiṣṇavakaraṇa* in Śaka 1688. Although he has observed in the beginning that he proposed to compile it according to Viṣṇugupta's views, he has, in reality, followed the Bhāskarācārya's views. He perhaps meant to name Brahmagupta, son of Jiṣṇu, in place of Viṣṇugupta. This work adopts a Zero ayanāṃśa for the Śaka year 445. The work contains about 300 verses. It is claimed that this Karaṇa work would give planets places agreeing with observation. But it contains nothing more than earlier works, Gaṇakataranginī, pp. 110-111.

GRAHAGAṆITA CINTĀMAṆI

BY

MAṆIRĀMA, Śaka 1696

BRIEF ACCOUNT

Maṇirāma was a Yajurvedī Brāhmaṇa belonging to Bhāradwāja gotra. The names of his three ancestors, starting from his father, were Lālamaṇi, Devīdāsa, and Līlādhara. His guru was one Vatsarāja of Kāśyapa gotra. All these names suggest that Maṇirāma was a Gujerāti. The verses describing his family history show that his name may have been simply RĀMA.

Outline of Work

The Grahagaṇita Cintāmaṇi has given epochal positions for the morning of Sunday, the first lunar day of Caitra Śukla, of Śaka 1696 (i.e. 13th March, 1774 A.D.). They are :—

	Sun	Moon	Moon's apogee	Moon's node
S	11	11	1	
°	0	4	29	15
′	15	50	6	36
″	1	6	21	55

	Mars	Mercury's (mean) elongation	Jupiter	Venus's (mean) elongation	Saturn
S . .	10	1	11	4	4
°	13	17	29	23	27
′	4	5	57	54	4
″	51	12	0	54	12

Difference from those of Grahalāghava (Gr. L.-23 cycles ; ahargaṇa=388)

	°	′	″		°	′	″
Sun . . .	+0	0	24	Mercury's (Mean) elongation .	+1	14	31
Moon . . .	+0	0	51	Jupiter	+0	20	33
Moon's apogee .	+1	36	8	Venus's (Mean) elongation . .	—2	56	34
Moon's node .	—0	17	22	Saturn	—0	9	17
Mars . . .	—0	6	37				

This work has employed the same device as Grahaghava in order that aha-rgana may not exceed a certain number.In other words it has assumed a cycle of 11 years and the explement of the motion during this cycle is termed 'Dhruva'. These 'Dhruva' figures are more accurate than those of Grahalāghava. The author is a follower of the Sūrya Siddhānta ; still, he has not adopted the positions as they are actually obtainable from the Sūrya Siddhānta. Again, though the method of procedure adopted in the work is almost the same as that of Grahalāghava, the author has not relied upon that work too for the places of planets. From this and from his remark in the conclusion, viz. "I have compiled this work, after myself taking observations, according to the methods of observation described by learned men. Scholars may test their accuracy by means of instruments," it appears that the writer has obtained the planets' places at the epoch, after actually taking obervations for himself.

He has mentioned a correction due to difference in longitude (rekhāntar) to mean places of planets. Similarly, he has mentioned the corrections of 'bhujāntar' and 'cara' for all planets'. The ayanāṃśas have been given according to the Sūrya Siddhānta. The method of calculating true places of planets is like that of Grahalāghava. However, the figures for the helio-centric and geocentric positions are somewhat different.

The work contains 12 chapters on the following subjects :—mean places, true places of the sun and the moon, true places of planets, calculation of the ascendant etc., lunar eclipse, solar eclipse, graphs, re-appearance of the moon, construction of the 'nalikā' instrument, elevation of moon's cusps, heliacal rising and setting and Mahāpāat. The number of verses in it are respectively 19, 11, 14, 7, 5, 3, 7, 3, 26, 4, 6, 15, i.e. 120 in all. There is a copy of this work in the Ānandāśrama (library), Poona. (Book No. 3103).

No Setback to Grahalāghava

A number of attempts appear to have been made to compile a work similar to the *Grahalāghava*. The author has not found among these any work as good as this one. Of course the author of this work cannot be credited with capacity for original work like that of the *Grahalāghava* ; still, it is only fair to observe that he has given planetary positions agreeing with observed results ; and, judged only as a karaṇa grantha, this work is by no means inferior to the Grahalāghava. Nevertheless, Grahalāghava has been in extensive use all over the country and in spite of its great antiquity it is not found inconvenient for calculation. Moreover, many astronomers have prepared tables in order to simplify all its calculation work. For all these reasons the Grahalāghava has not been beaten as yet by any of its successors.

BRAHMA SIDDHĀNTASĀRA, Śaka 1703

This is a work belonging to Brahmapakṣa. It contains 12 chapters. It has adopted Śaka 1703 as its epochal year. The first chapter comprising 124 verses, is a synopsis of the chapter on mean places from the Siddhānta Śiromaṇi. Then follows the main part of the original work. It follows the method of computing planets' places from ahargaṇa. Some of its methods are similar to those of the Grahalāghava. The author of the work, named BHULĀ, was the son of Nārāyaṇa and a devotee of goddess Devī ; he was a Brāhmaṇa belonging to Gārgya gotra, and used to reside at Dadhīci, a place 6 miles to the east of the mouth of the Narmadā.

YANTRARĀJA GHAṬANĀ

BY

MATHURĀNĀTHA, Śaka 1704

Mathurāntāhā, a Mālviya Brāhmaṇa, was employed in the library of the Sanskrit Pāṭhśālā* at Vārānasī from 1813 to 1818 A.D. (Śaka 1735 to 1740). He was a good scholar of astronomy and knew the Persian language. He compiled the work Yantrarāja Ghaṭanā in Śaka 1704. The number of verses in it is about 1000. He received the patronage of Dayālu Cānd (Dalcānd), grandfather of Śivaprasad, the well known king of Vārānasī. The latitudes and longitudes of stars observed in Śaka 1704 have been recorded in this work. (Gaṇaka Taranginī, pages 114—6).

There is an instrument known as Yantrarāja which is useful for observation. There is also an old work entitled " Yantra Rāj ", dated Śaka 1292, which has been noticed further in the chapter on observations. Mathurānātha's work probably dealt with the construction of the instrument, the method of taking observations and the like matters.

CINTĀMAṆI DĪKṢIT

This astronomer flourished under the Peśwa rule. His date of birth is about Śaka 1658 and the date of death Śaka 1733. He was given a pension of Rs. 125/- by the Peśwas. He was a resident of Sātārā. He prepared tables for the *Sūrya Siddhānta*; he compiled in Śaka 1713 a work entitled Golānand, which is devoted to the instruments of observation. Its description will appear in the chapter on 'Observations'. There is a commentary on it compiled by Yajñeśwar alias Bābā Jośī Roḍe. The descendants of Cintāmaṇi are at present residing at *Sātārā*. The author had met in Śaka 1809 Bhāū Dikṣit Ciplūṇkar, the grandson of Cintāmaṇi Dikṣit. The above account is given on the basis of the information given by him personally and also from what could be gathered from the work. It was told that he had a brass instrument called Golānand and the directions etc. have been fixed in *Sātārā* for the purpose of taking observations. It is mentioned in the Golānand, that Cintāmaṇi's gotra was Vatsa, his father's name Vināyaka and the original place of residence of his ancestors was Ciplūṇ.

RĀGHAVA

He was a resident of *Pārola* in Khāndeś, at about 2 'yojansa' to the south of the river Tāpī. He used to reside also at '*Puṇyastaṃbha*' (Puṇtaṃba) on the bank of the Godāvarī, in Ahmednagar district. He compiled some of his works there. His surname was Khandekar and his father's name was Āpāpanta.

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*The Sanskrit School (Pāṭhaśālā) at Vārānasī was established by Jonāthan Duncan, the Resident of Vārānasī, on 28th October 1791 (Śaka 1713). The school is still in existence. The ancient Indian sciences and modern sciences like mathematics etc. are taught there through the medium of Sanskrit.

He compiled two astronomical works, Kheṭakṛti aud Pañcāngārka, and a work on astrology, entitled Paddhati Candrikā. Kheṭakṛti belongs to Śaka 1732. It may be regarded as following the *Grahalāghava*. It treats of only the very necessary subjects from the *Grahalāghava*. The figures for motions and other measures are more crude than those of *Grahalāghava*. He has adopted different devices for calculating mean places of planets. This work is in some respect more convenient for calculation than even the *Grahalāghava*. The author has incorporated in it also the methods of calculating tithis and other features of the almanac from the epochal positions for his own date, after quoting relevant verses from the *Tithi Cintāmaṇi*. On the whole, however, it is very inferior to the *Grahalāghava*. But it is better than Rāghava's second work 'Pañcāngārka.' The Pañcāngārka belongs to Śaka 1739. Rāghava compited it, because the earlier compilers of works on Pañcānga calculation used to keep secret the reasons underlying such terms as 'abdapa' occuring ih them. The commentary on the work is written by the author himself. It was compiled at Puṇtāmba. This work alone would not serve the purpose because, it instructs one to adopt the *parākhya** correction from the *Laghu Cintāmaṇi*. Again the author has given the method of calculating only the mean places, white that for the true places has not been dealt with. One fails to see why then the calculation of mean places is given at all. The length of the year has been taken as 365d-15-31-31. The mean places are to be found from *Varṣagṇa*. But the annual motions given for this purpose appear to be very approximate as compared with those of the *Sūrya Siddhānta*. The motions have not been altered with any definite purpose in view. The second chapter deals with the calculation of the ascendant and the 3rd and the 4th describe how to calculate the eclipses of the sun and moon, provided the "nakṣatra" is known. The four chapters together contain 103 verses.

Paddhati Candrikā, a work on astrology, was compiled in Śaka 1740. It was completed at Pūṇyastambha. Āppāgoswāmi, son of Rāma, śurnamed Khire, and a resident of the village Revaḍa, situated in the territory between the rivers Kṛṣṇā and Nirā, wrote a commentary on it in Śaka 1741, which is entitled Lalitā.

TITHI PĀRIJĀTA BY ŚIVA

Śiva, the son of Mahādeva, belonging to Viśwāmitra gotra, was a resident of *Lakṣmeśwara*. He compiled the work, Tithipārijāta, in Śaka 1737. It follows the Grahalāghava. It gives tables like those of Tithi Cintāmani, for the calculation of tithis. (This information has been given from the *Gaṇaka Taranginī*). It is not known if this Lakṣmeśwara is the same as that in Dharwar District.

DINAKARA

BRIEF ACCOUNT

A numbsr of works compiled by Dinakara and copied out by Mādhavarāo Penḍse of Poona, are in the Ānandāśrama, *Poona*. In an example in one of the books, the *palabhā* taken is 4 and the longitude is 28 yojanas west. These are the corrdinates for Poona. From this, Dinakara appears to have been a resident of Poona. According to the description given in his commentary on the Yantra-Cintāmaṇi, the name of Dinakarara's father was Ananta and his gotra was Śānḍilya.

*Parākhya is the duration of the unexpired part of *tithi*, *yoga* or *naksatra* at sunrise.

WORKS

All his works on astronomy have been compiled with a view to simplifying planetary calculations to be made according to the *Grahalāghava*. They consist mostly of tables, and are very useful for study, because solved examples have been given in them. The works are :—(1) *Graha Vijñāna Sāraṇī* : This contains tables useful for calculating mean and true places of planets. The Śaka years used in the examples are 1734, 39, and 44. (2) *Māsa-praveśa-sāraṇī* shows how to compute the true daily position of the sun, for the sake of finding the moments of the commencement of a new day, a new month, and a new year of life, according to Tājaka system. The solved example has adopted 1744 as the Śaka year, 4 as the palabhā, and 28 W. Yojanas as the longitude. (3) Lagna Sāraṇī : tables for finding ascendants. (4) Krāntisāraṇī : tables for finding the declination. Śaka year 1753 has been selected for the example. (5) *Candodayāṅkajāla* : Śaka year 1757 adopted in the example (6) *Drikkarma Sāraṇī* : Śaka year 1758 taken for the example. (7) *Grahaṇāṅkajāla* : The example has adopted Śaka 1755—1761 as the years (8) *A commentary* on the Pātasāraṇī (Tables for the calculation of Mahapāta) by Gaṇeśa Daivajña, Śaka 1444. The example adopts Śaka 1761 as the year. (9) *Yantra Cintāmaṇi-Ṭīkā* : This is a commentary on the work on instruments by Cakradhara.

Dinakara was an ingenious astronomer and his works show that he had a good knowledge of observations.

GRAHALĀGHAVA METHODS SIMPLIFIED

A number of astronomers possess tables like those prepared by Dinakara that are useful in making any calculation by the Grahalāghava methods and especially for finding the mean and true places of planets. The calculation which normally takes 2 to 2½ hours if done according to the method described in the Grahalāghava verses, can be finished in nearly half an hour with the aid of such tables. VĀMAN KṚṢṆA JOŚĪ, Kannaḍkar, published in Śaka 1803 a work, entitled, " Bṛhat-Pañcāng-Sādhanodāharaṇa " which contains such tables. The printed version of 'Keśavi (collected works of Keśava, the father of Gaṇeśa Daivajñya) contain similar tables. Nevertheless astronomers are found as do not have any idea of such devices and short cuts and are consequently required to follow the laborious method of calculation.

YAJÑEŚWARA ALIAS BĀBĀ JOŚĪ RODE

BRIEF ACCOUNT

His gotra was Śāṇḍilya, his father's name was Sadāśiva and that of his grand father, Rāma. He was the grandson (daughter's son) of Cintāmaṇi Dīkṣit of Sātārā. When British rule was established in Mahārāṣṭra, a Sanskrit College was founded in Poona, and Yajñeśwara was a teacher* of astronomy there up-to September 1838 (Śaka 1760). From what date he was there, is not known. The chief Paṇḍit and astronomer, Subājī Bāpū, of the Sanskrit School at Sihore,

*Mr. Chaplain, Commissioner of Southern Division, founded the Poona Sanskrit College in 1821 A.D. Afterwards the College underwent such a complete transformations in 1851 A.D. that it may as well be regarded to have ceased to exist. (See Report of the Board of Education, for 1840, 41, 51 & 52.)

in Malwa, had compiled a small work entitled Siddhānta Śiromaṇi Prakāśa in which he presented a comparative study of the mythological views abou) astronomy, those of the Sanskrit astronomical siddhānta works, and thost of Copernicus. R.B. Godbole, author of the *Modern History of India* (Marāṭhīa writes that Yajñeśwara had compiled the work, " Jyotiḥ-Purāṇa- Virodha Mardan " in refutation of the work of Subājī Bāpu while Major Candy has observed that Yajñeśwara was very intelligent and learned, but a very bigoted champion of the mythological doctrine. But there is still another work 'Avirodhaprakāśa' by Nīlkānṭha, in which it has been shown that there is no contradiction between the teaching of the Purāṇas and those of the science of astronomy. Wilkinson, the Political Agent of Sihore, had a sound knowledge of Indian astronomy. He had got Siddhānta Śiromaṇi, printed at Calcutta in 1841 A.D. (Śaka 1763). It was on his advice that Subājī Bāpū compiled another work " Avirodhaprakāśa viveka " (Śaka 1759) in order to refute the arguments advanced in " Avirodhaprakāśa ", and sent it to Bābā Jośi at Poona, and Bābā Jośi endorsed the views of the author, as can be seen from the relevant correspondence published in the original by the author of the *Gaṇakataraṅgiṇī**.

WORKS

The following are the works by Yajñeśwara :—His commentary, Yantrarāja Vāsanā, on the work, Yantrarāja, belongs to Śaka 1764. He has also written Anubhāvikā, a commentary on Golānand by Cintāmaṇi Dīkṣit. The commentary, Maṇikānti, on Laghu Cintāmaṇi, compiled by some Yajñeśwara may probably be the work of this very author. These works show that Yajñeśwara had a sound knowledge of Siddhānta works. He has referred to his work entitled, Praśnottarmālikā in his commentary on Golānand.

NṚSIṂHA, alias BĀPŪDEVA, Birth Śaka 1743

Brief Account

Bāpūdeva was one of those learned men who lived after the establishment of the British rule in India and who were proficient both in the Indian and Western systems of astronomy and mathematics. He was a Rīgvedī Citpāvan Brāhmaṇa, originally a resident of *Ṭonke*, on the bank of Godāvarī in Ahmednagar district. He was born on the 6th lunar day of the bright half of Kārtika in Śaka 1743 (i.e. 1st November, 1821). His father's name was Sītārām and mother's name Satyabhāmā. He received his elementary education in a Marāṭhī School at *Nagpur*, and in the same city he studied Bhāskara's Līlāvatī and Bījagaṇita, under the guidance of Ḍhunḍhirāja, a Kānyakubja Brāhmaṇa scholar. In Śaka 1760, L. Wilkinson, the Political Agent at Sihore, was impressed by Bāpūdeva's proficiency in Mathematics and took him to the Sanskrit College (Pāṭhśālā) at Sihore for further study. Here he studied Geometry and other branches of mathematics under the care of Sewā Rām. Afterwards, on Wilkinson's recommendation, he was appointed a teacher of Geometry in the Sanskrit College at Vārāṇasī in Śaka 1763 (i.e. 1841 A.D.) From that

*Śivalal Pāṭhak of Vārānasī had compilied a work entitled Siddhānta Manjuṣā, which was meant to refute the arguments of the Avirodhaprakāśa. Similarly, Bālakṛṣṇa, a disciple of Śivalal's younger brother had written a work " Duṣṭa-mukha-capetikā ". Both these (works) had been compiled before Saka 1759.

day he lived at Vārānasī till his death. He became the Head Teacher of mathematics in the same College. He retired from service in Śaka 1811. Afterwards, he died in the month of Vaiśākha in Śaka 1812, at the age of 69.

A number of students received their training under his supervision. He became an Honorary member of the Royal Asiatic Society of Great Britain and Ireland in 1864 A.D. and that of the Asiatic Society of Bengal in 1868 A.D. In 1869, he was made Fellow of the Calcutta University. He was also a Fellow of the Allahabad University. In 1878, he received the title of C.I.E., and in 1887 that of Mahāmahopādhyāya from the British Government on the occasion of the Golden Jubilee of the Queen Empress. The ruler of Jammu once awarded him a cash prize of Rs. 1,000 - for having correctly predicted a lunar eclipse.

The works compiled by him were :—(1) First chapter of Geometry (2) Part of a work on Trigonometry (3) The controversy about the Sāyana-system (4) A brief account of the teachings of ancient astronomers (5) Eighteen questions on strange subjects with their answers. (6) Tattvaviveka parīkṣā (7) A description of the instruments at Mān Mandir. (8) Arithmetic. All these works, both small and large are written in Sanskrit and all of them have been printed. In addition to these he wrote (i) 20 verses to explain the theory of Calculus, (ii) some formulae of spherical trigonometry (iii) useful notes on the study of siddhānta works (iv) The Chedyaka, useful for Yantrarāja, and (v) the Laghu-Śaṅku-chinna-kṣetra-guṇa. These have not been printed. His Hindi works on Arithmetic, Algebra and Astrology have been printed. He examined the English translation of the Golādhyāya from Siddhāntaśiromaṇi by L. Wilkinson, and he himself translated the Sūrya Siddhānta. Both these works were prepared under the supervision of Archdeacon Pratt and printed in 1861-62. He also published with critical notes the Gaṇita and Gola, parts of Bhāskara's Siddhānta Śiromaṇi, in Śaka 1788 and the work Līlāvatī in Śaka 1805.*

Every year Śaka 1797 to 1812, he used to publish an almanac with the help of the *Nautical Almanac*. A description of the Almanac will appear hurther in the course of our study of Pañcāṅga. He did not, however, compile any work on the method of the computing the Pañcāṅga.

NILĀMBAR ŚARMĀ, Śaka 1745.

He was a Maithili Brāhmaṇa, residing at Pāṭalīputra (Patna), four miles from the conflunce of the Ganges and the Gaṇḍakī. His father's name was Śambhu Nāth. He studied under the care of his elder brother, Jeevanāth, and later on for some days in the Vārānasī Sanskrit College. He was the Head astronomer at the court of Śiva, King of *Alwar*. He died at Vārānasī in Śaka 1805.

He compiled a work 'Gola Prakāśa' in Sanskrit in the western style. Bāpūdeva printed it at Vārānasī in Śaka 1793. It contains five chapters. The following subjects are dealt with in it :—The conception of sines, the theory of (plane) trigonometry and spherical geometry, and the theory of spherical

*This account is based mainly on the *Gaṇakataraṅgiṇī*.

trigonometry and problems. This work is very useful for those who do not understand English. He has written a commentary on some sections of Bhāskara's works. His elder brother Jeevanāth, wrote a commentary on Bhāskara's Bījagaṇita and astrological works like Bhāva Prakāśa.

VINĀYAK alias KERO LAKṢMAṆ CHHATRE, Birth Śaka 1746.

Brief Account.

Keropant Nānā was one of the renowned scholars who were proficient in Western learning and who flourished after the British rule became established in Mahārāṣṭra. He was particularly proficient in mathematics, astronomy and nature study. There is a coastal village, named Nāgāon, in Aṣṭāgar Prānt, about 26 miles to the south of Bombay. He was born there in May 1824. He was a Rīgvedī Citpāvan Brāhmaṇa, belonging to the Kāśyap gotra. He completed his studies of the English language and through that medium, the study of Western sciences at the Elphinstone Institute of Bombay. He was a pet student of Prof. Arlibar.

In the year 1840 A.D. an Observatory was built at Colaba, Bombay, to observe the celestial phenomena and to test the effects of magnetic attractions. When it was inaugurated by Prof. Arlibar, he appointed Keropant as an Assistant there. Later, on 7th June, 1851, the Poona Sanskrit College was converted into the Poona College ; and after some months, Keropant was appointed Assistant Professor to teach mathematics and natural Sciences to the Marāṭhī section and the Normal School. He used to teach these subjects. in the College through Marāṭhī as well as English. Later ón, the Normal School section was separated from the College, and he worked as a teacher, and later on, he worked for some years more as Superintendent of the School. The Institution was also known in those days as Vernacular College. (It is at persent known as the Training College). In those days he used to lecture also in the Engineering College on the subject of Natural Science. Some time during this period he was the Head Master of the English School at Ahmednagar. In 1865, he was appointed a Professor of Mathematics and Natural Science at the Poona College, where he used to teach these subjects through English. The College, later on came to be known as the Deccan College. He retired from service in 1879 A.D. He was, at that time, drawing Rs. 1,000 per mensem and he received a pension of Rs. 5,000 per year, the maximum which a 'Native' could receive in those days. In 1877, he received from the British Government the title of 'Rao Bahadur' on the occasion of the Delhi Durbar. He died on 19th March, 1884, at the age of 60. He was popularly known as 'Nānā. His lifelong scholarly habits and his inmate goodness were the most notable and praiseworthy among his many fine qualities.

Works.

About Śaka 1772, Nānā compiled in Marāṭhī, a work entitled, *Grahasādhanācī Koṣṭake* (Planetary Tables) with the help of French and English works on astronomy, and published it in Śaka 1782, (1860 A.D.)*. There was no such work compiled before, either in Marāṭhī or Sanskrit, and hence it renks very high among works of similar nature.

*Kṛṣṇaśāstrī Godbole writes that it was compiled on the basis of a work published by R. S. Vince in 1808 A.D.

In this work, the length of the year is assumed to be the same as in the Sūrya Siddhānta ; and the positions and motions of planets have been adopted on sāyana basis. Hence, the planets' places calculated from this work are tropical or sāyana. The author has assumed Zeta Piscium to be the junction star of Revatī. It coincided with the vernal equinox in Śaka 496. We are asked to find the nirayaṇa places of planets, by assuming the ayanāṃśa to be zero in that year, and by applying the ayanāṃśa correction to the sāyana positions at the rate of 50″·1 per annum. The whole process amounts to the adoption of the correct length of the sidereal year, *viz.*, 365^{d}-15^{g}-23^{p}. Adopting this length of the year and 50″·2 as the annual rate of precession, Keropant Nānā began to publish since Śaka 1787 a separate almanac with the help of the Nautical Almanac. The late *Ābāsāheb Paṭwardhan* gave him very valuable help. It was due to his encouragement that the above work could be compiled and the almanac was published from year to year. The almanac was naturally entitled by Nānā as 'Pātwardhanī Pañcāṅga'. The positions of planets calculated from Nānā's work is fairly accurate ; but the work and the Patwardhanī Pañcāṅga are not now in use, and it may safely be said that no one follows the almanac. This almanac will be described in more details further on.

Nānā compiled a work on the calculation of tithis on the lines of the Tithi Cintāmaṇi. It has been printed in Vārānasī. No one could be found in this province to print it. It is almost unknown in this province, and this work as well as the *Grahasādhanācī Koṣṭake* are both out of print at present.. The *Graha Sādhana* has not adopted the purely sidereal year and the places of planets are sāyana. Hence, the work, as it stands, is of no use in directly computing a Pañcāṅga belonging to any of the schools, *viz.* nirayaṇa according to the *Grahalāghava*, purely nirayaṇa or purely sāyana. Besides this it requires the use of logarithms and trigonometry ; and hence, the orthodox astronomers, are unable to make calculations from the work ; and it is doubtful if even half a dozen persons could be found among the newly educated people who could calculate from it.

Nānā wrote two books for Marāthī schools. They are :—(i) Physics and (ii) Arithmetic. Mahārāṣtra can boast of thousands of people who could be called his disciples, direct or by tradition.

VISĀJĪ RAGHUNĀTHA LELE, Birth Śaka 1749.

Brief Account.

One of the most talented and ingenious astronomers that ever flourished in our country, Lele was born at *Nasik*, on Friday, the tenth lunar day of the dark half of Śrāvana, in Śaka 1749 (*i.e.* 1827 A.D.), the ascendant at birth being Capricorn. He was a citpāvan Brāhmaṇa of the Hiranyakeśī Branch of Kāśyap gotra. In his childhood he received some education in the Marāṭhī school at Nasik till he was 11, where be learnt arithmetic up to fractions, and he received some lessons in Sanskrit while residing with his maternal uncle. This was the only education imparted to him by teachers, but owring to his perseverance and intelligence he was able to solve mathematical problems that would baffle even University graduates in spite of their background of English education.*

*Lele was known to me personally and throughc orrespondence. Most of this account has been written on the basis of this personal contact. A sketch of his life was published in the October 1888 issue of the monthly journal Balbodh.

Having passed some years in some trivial employment, he went to Gwalior about Śaka 1782. He was there employed in the Revenue Department and the Accounts Department of Scindia Govt. His Bālbodh and Moḍī handwriting was excellent. He was also very good at map drawing ; and not a single mistake was ever found to have crept into his accounts. Having put in 33 years service he retired about Śaka 1816 and he died at Gwalior in his 69th year, on Friday the 6th lunar day of the dark half of kārtika in Śaka 1817.

Sāyana Pañcāṅga

Many persons feel that the almanac should be sāyana. Many must have felt and did actually feel thus before Lele. The thought naturally crossed Lele's mind and he was convinced that the 'sāyanapañcāṅga, alone could be said to be in conformity with the tenets of religion. For some days, he used to compile a sāyanaalmanac for practical use with the help of the *Grahalāghava,* and later on with that of the *Nautical Almanac.* But he did not get any opportunity for publishing it for some years. He had acquired a working knowledge of English that enabled him to compute figures from the *Nautical Almanac.* Keropant began to publish an accurate nirayaṇa almanac from Śaka 1787 (*i.e.* 1865 A.D.). From that year Lele carried on a controversy with Keropant through the press under the nom-de-plume "Sphuṭavaktā Abhiyogī", (candid combatant) in order to convert Keropant to the Sāyana view. Keropant remained indifferent and Lele, finding that he (Keropant) did not appear to be impressed by the importance of publishing a sāyana pañcāṅga, which would conform to the tenets of religion, began to publish independently a sāyanaalmanac with the help of other co-workers from Śaka 1806. We shall have to revert to this almanac later on in the chapter on *Pañcāṅga.*

Lele did not compile any work from which to compute a sāyanapañcāṅga, and hence, the task of popularizing it is a matter depending upon outside factors.

CINTĀMAṆI RAGHUNĀTHA ĀCĀRYA

(Birth Śaka, 1750)

Brief Account.

He was for 17 years the First Assistant in the Astronomical Observatory at Madras. Cintāmaṇi Ṛaghunātha Ācārya was an authority in the Madras Presidency just as Keropant was in this province and Bāpūdeva in the region around Vārānasī. He was born on the 6th day of the PAṄGUNI month of the Sarvajit Saṃvatsara in Śaka 1749, according to the solar reckoning, or on the 2nd lunar day of the bright half of Caitra of Śaka 1750, by the luni-solar reckoning *i.e.*, on 17th March, 1828. His mother tongue and the birth region appears to be Tamil (Dravid). He has himself written that he did not understand Sanskrit. Still he had a very sound knowledge of European astronomy and mathematics, and hence, that of Indian astronomy also. He actually used to take observations for a number of years. He was very well known in that respect. He was a Fellow of the Royal Astronomical Society in England since 1872. In 1847, he entered service in the Madras Observatory and he remained there till the end. He died on 5th of February (*i.e.* Pauṣa) in Śaka 1801, in his nd year. He belonged to a family of astronomers. His father

also had been an Assistant in the Madras Observatory. A catalogue of stars has been compiled by the Madras Observatory, for which observations of many of the stars were taken by Cintāmaṇi himself. He discovered two variable stars in 1867 and 1878. He was the first Hindu astronomer whose name is associated with a discovery of this nature.

Works etc.

He compiled a work entitled *Jyotiṣa Cintāmaṇi.* It consists of three parts. The first deals with mean motions, the size and magnitude of the earth and other planets etc. The second is devoted to their true places and motions and the third, entiled 'Karaṇa paddhati', contains tables for planetary calculations. This work appears to have been compiled in the Drāviḍian (*i.e.*, Tamil) language originally. A meeting was held in Madras in 1874 A.D. and the decision taken to arrange to publish its Sanskrit translation in the Tamil, Telugu and Devanagari scripts. It was estimated that the cost of the publication would be Rs. 7,000 for 500 copies, the whole work comprising about 800 pages of demi octavo size. The book however, was never printed.*

He used to publish an almanac, entitled *Dṛggaṇita Pañchāṅga* with the help of the *Nautical Almanac.* The author has seen an almanac for Śaka 1808, published after his death by his two sons. It seems to have adopted 22°5′ as the ayanāṃśa and the length of the year as given in the *Sūrya Siddhānta.* The elder son C. Rāghavācārya died about Śaka 1811. His younger son and brother-in-law, P. Rāghavācārya, the First Assistant in the Madras Observatory, jointly publish the almanac at present.

KṚṢṆA ŚĀSTRI GOḌBOLE, Birth Śaka 1753.

Brief Account.

He was a Citpāvan Brāhmaṇa, belonging to the Hiraṇyakeśi branch and of the Kauśik gotra. He was born on the 10th lunar day of the dark half of Śrāvana, Śaka 1753 (*i.e.*, on 1st September 1831) at Waī. He studied, in the beginning, in a Marāṭhī school at Poona and then at the Sanskrit Pāṭhśālā and the Poona College. He had a liking for mathematics from his very childhood. At the Sanskrit college he studied astronomy under the care of Śaṅkar Jośī. On the 19th of October, 1855, he was appointed a teacher in the Normal School of the Poona College. There he mainly taught mathematics. For some time during 1864-65, he had been appointed in the Colaba Observatory, Bombay. In 1865 he was again appointed in the Poona Training College. In 1866, he was transferred to the Hyderabad High School, Sind, and in 1867 to a High School at Karachi. In 1872, he worked as Asstt. Teacher in the Poona High School and later on for some days more in the Elphinstone High School, Bombay. Later on, in the same year, he was made the Head Master of the Anglo-Marāṭhī School, Phanaswāḍī, Bombay, and he remained there till March, 1882. Later on, he began to reside in his home at Poona, after

*In 1874, there was a transit of venus across the disc of the Sun. Raghunātha Ācārya had got its calculation published in several languages. His pamphlet in English contains an account of this laborious task. The auther has given the accont of Raghunātha Ācārya, mainly on the basis of this pamphlet and also from the information published n newspapers and sent to him by the well-known Nateś Śāstrī of Madras.

his retirement from Service. He died on 22nd November, 1886. While he was in Sind, he studied the Sindhi language thoroughly and learnt even Persian. He used to be an examiner for the Sindhi language, in the Bombay University, from 1871 to 1879.

Works.

He and Wāman Kṛṣṇa Jośi Gadre, jointly translated the *Grahalāghava*, with examples, into Marāṭhī and published it in Śaka 1778. It is almost a translation of the Viśwanāthī commentary. A second edition of this work is now published. Kṛṣṇa Śāstrī has also written a book on the theory underlying the *Grahalāghava* in Marāṭhī and it is learnt that he has corrected in it the errors in the Mallārī commentary. It is worth publishing. In addition to this, a short article of his, on the history of astronomy, written about Śaka 1807, has come to the author's notice. The *Jyotiṣśāstra*, a Marāṭhī book written on the basis of Chambers's book in English, was printed and published in 1862 A.D., but it is not now in use. A Marāṭhī translation of *Hudson's* Algebra, had already existed ; he published it in 1854, after correcting it. It was in use in the Education Department for several years. In 1874 A.D., he and Govind Viṭhal Karkare translated in to Marāṭhī four parts of Euclid's geometry. Before this date, a Marāṭhī translation of Euclid's geometry by Nānāśāstrī Apṭe was in use in schools. Later on, from 1885 A.D. the book, by late R.M. Devakule, came into use. In 1882 A.D. Kṛṣṇa Śāstrī published an article entitled "Antiquity of the Vedas" in the Theosophical magazine and also got it printed separately. The author does not think that it contains any evidence on the strength of which it could be proved beyond doubt that the Vedic period was more ancient than 1200 B.S. (before Śaka). He attempted to prove that the antiquity of the Vedas extends beyond 30000 B.S., by interpreting the line "māsānāṃ Mārgaśīrṣohaṃ" from the Gita, as indicating that "the equinox used to occur in Mārgaśīrṣa". He published a book on Arithmetic in Sindhi in 1869 and a good book on Marāṭhī Grammar also in Sindhi in 1867 A.D. Its popularity is proved from the fact that it went through its third edition in 1895*. He also published in 1868 A.D. a book on the Sindhi language.

He had once published his view that the calculation for the five parts of the *Pañcāṅga* should be made on the basis of the mean places of the Sun and the Moon.

Wāman Kṛṣṇa Gadre, referred to above, published in Śaka 1791, a work entitled *Pañcāṅga-sādhanā-sār*. It contains a Marāṭhī translation of the *Laghu Cintāmaṇi*, along with examples. The tables, however, contain a good many errors.

Living Authors of Astronomical Works,

1. *Venkaṭeś Bāpūjī Ketkar :—*
(Birth date :—Friday, the 14th lunar day of the bright half of Pauṣa, Śaka 1775).

*This has been printed by Ananta Kṛṣṇa, the son of the Śāstrī, who has given in it, the biography of Kṛṣṇaśāstrī. The above account has been given on the basis of the biography as well as the information collected by the author.

He is a Rlgvedī Citpāvan Brāhmaṇa belonging to Gārgya gotra. He is working as a teacher in the Education Department in this province since 1874 A.D. He has been the Head Master of the English High School, at *Bagal-Kot*, for the last several years. He received most of his education at Belgāon. His father also was a good astronomer. He had rendered into Sanskrit Keropant's Planetary Tables, but it was not printed. For the last five or six generations the family had been living at Paiṭhaṇ. But Bāpū left the place for Nargundās and later on shifted to Rāmdurgās. He had the patronage of the Chief of that State.

Venkaṭeś compiled a very useful work in Sanskrlt, entitled "Jyotir-gaṇita" about Śaka 1812. He has adopted in it, Śaka 1800 as the epochal year. This has been compiled on the basis of those French works which are being used in compiling the *Nautical Almanac*. The planets' places, calculated with the help of this work, are very accurate, in fact they are correct within 1′ as compared with those of the *Nautical Almanac*. Never before has such a work been compiled in this province, not even in our country. This work has adopted for the length of the year the correct value of the sidereal year *viz.* 365d-15-22-53 and 50″·2 (the actual value) as the annual rate of precession. Assuming Zeeta Piscium to be the junction star of Revatī, he has given its sā yana longitude, or in other words, the ayanāṃśa for the Śaka year 1800 as 18° 10′ 25″. The author had suggested to him to adopt for the aya-nāṃśa a figure approximately equal to that of the *Grahalāghava*. A star whose longitude would be equal to it could have been adopted as the initial point. But even Ketkar has come to realise the fact that the ayanāṃśas can be nearly equal to those of Grahalāghava, by assuming 180° as the longitude of the star Citrā (Spica). In short, if he had assumed 22° as the aproximate ayanāṃśa for Śaka 1800, the author feels that Ketkar's work would have easily come into general use. The work mainly consists of four parts. The first contains the calculation of the almanac. The epochal positions are all given for the moment of the true Aries Ingress. The second part treats of the calculation of the places of planets. It includes the mean and true longitudes of planets, the right ascension, longitudes of star etc., heliacal rising and setting of celestial bodies, and other subjects. The third contains the calcula-tion of phenomena like eclipses, conjunctions, elevtaion of moon's cusps. The fourth contains the calculation of the ascendant etc. required in the case of three problems. The treatment of each subject has, everywhere in the book, adhered to the following order :—Method, example, tables and then the theory. The work contains tables for almost all calculations, and the calculators who do not understand the use of trigonometry and longarithms can easily make calculations from the book. Keropant's almanac can be compiled with the help of this Book. This book has not been printed as yet.

(2) *Bāl Gangādhar Ṭilak*

(Date of birth :—Wednesday, the 6th lunar day of the dark half of Āṣāḍna of Śaka 1778, the ascending sign being Cancer.). He is familiar not only in this country but even in foreign lands. He was for many years the Chief Professor of mathematics and astronomy in the Fargusan College.

He wrote a book in English entitled *ORION*, in 1893 A:D. (Śaka 1815) in which he has discussed in an accurate and elaborate manner the question of date of the Vedas and shown that some of the Vedic hymns were compiled when the vernal equinox was situated in the Orion group of stars, that is, about 4000 years B.S.

(*3*) *Vināyak Pāndurang Khānāpurkar* :—(Birth in Śaka 1780).

He was a Rigvedi Deśastha Brāhmaṇa, belonging to Jamadagnya gotra and a resident of Khānāpur, in Sātārā district. He has studied Sanskrit, astronomy and other subjects in the orthodox manner and also European mathematics and astronomy under the guidance of Keropant Nānā Chatre and Rāoji Moreśwar Devakule. An Association known as the Veda-Śāstrottejak-sabhā was started in *Poona* from Śaka 1796 and he was examined by the Association in the subjects of Indian Astronomy and Sanskrit Grammar.

He has compiled a *tājak* work, entitled *Vaināyakeeya Dwādaśādhyāyī*, by which the annual reading of a horoscope can be given with ease. He has similarly written the following books in Sanskrlt :—The *Kundasār* ; the *Ardhakāṇḍa*, a versified Sanskrlt translation, of the general enunciations of all theorems in the two parts of Euclid's Geometry, and the Siddhāntasār. In the last named work, he has explained the question of the movement of earth etc. according to the modern European view. He has translated into Marāṭhı, Bhāskara's Līlāvatī, Bīja and Golādhyāya, adding an explanation of the theory and he is at present translating the Gaṇitādhyāya. These works are not yet printed.

(*4*) *Sudhākara Dwivedī* :—(Date of birth :—Monday, the 4th lunar day of the bright half of Caitra, Śaka 1782).

He is at present the Head Teacher of mathematics and astronomy at the Sanskrit College, Vārānasī. He was appointed in the place of Paṇḍit Bāpūdeva, after his retirement in Śaka 1811. He was formerly the Chairman of the Library Committee in the same College. The title of Mahāmahopādhyāya has been conferred on him by the British Government.

The following are the Sanskrit works compiled by him:—(1) The *Dirghavṛttalakṣaṇa* (śaka 1800). The author described in details the properties of the ellipse, along with its theory; (2) the *Vicitra Praśna* (Interesting problems), Sabhang, in Śaka 1801. This contains 20 difficult problems in mathematics, along with their solutions; (3) the *Vāstava Candra Śṛngonnati-sādhana*. After pointing out the defects in the calculation of the elevation of the moon's cusps by the methods advocated by Lalla, Bhāskara, Jñyānarāja, Gaṇeśa, Kamalākara and Bāpūdeva, he has given in this, the correct method of calculating it accurately with the modern methods of European astronomy. This contains 92 verses; (4) the *Dyucara Cāra* (Śaka 1804). This contains a discussion of the orbital paths of planets according to modern European astronomy; (5) *Piṇḍa-Prabhākar* (Śaka 1807). This is a work devoted to the subject of house building; (6) the *Bhābhramarekhānirūpaṇa*. This is devoted to the consideration of the subject of "Sūcī-Chedana" corresponding to a given shadow; (7) the *Dharābhrama*: It considers the diurnal rotation of the earth; (8) the *Grahaṇa Karaṇa*. This describes the method of calculating an eclipse; (9) the *Golīya*

Rekhāgaṇita i.e. Spherical Geometry; (10) A Sanskrlt translation of the 6th, 11th and 12th books of Euclid, in verse form, and (11) the *Gaṇaka Taraṅgiṇī* (Śaka 1812). It contains a history of Indian astronomers. It was, in the beginning, published in *Paṇḍit*, a monthly journal of Vārānasī. It was published separately in book form later on in Śaka 1814 and containts 124 pages of octavo size. Most of the remaining works have been printed. The following are the commentaries edited or written by Sudhākara :—He edited the *Yantrarāja* in Śaka 1804, along with the commentary, *Pratibhā Bodhak*, dated Śaka 1795, as also the commentary by Malayendusūrī. He published Bhāskara's *Līlāvatī*, with a new theory and certain special features in Śaka 1800. He also published Bhāskara's "Bīja" with a new commentary. He wrote a commentary, "Vāsanā Vibhūṣaṇa" on Karaṇa Kutūhala, which was printed in Śaka 1803. He wrote in Śaka 1810, a commentary named "Pañcasiddhāntikā Prakāśa" on Vārāha's *Pañcasiddhāntikā*. The work containing the commentary, along with an English translation of the original by Dr. G. Thibaut, the then Principal of Vārānası Sanskrit College, was published in 1889 A. D. All these commentaries are written in Sanskrlt. In addition to these, he edited and published the 'Chādak Nirṇaya' by Kṛṣṇa, "Siddhāntatattva-viveka" by Kamalākara and "Dhīvṛddhida tantra" by Lalla, in the Śaka years, 1806, 1807 and 1808, respectively. He is at present engaged in getting the revised edition of the Bṛhat Saṃhitā with Utpal Tīkā through the press. He has compiled a work, "Bhāṣā bodhaka", in Sanskrit, about (the teaching of) a language. He has written two books in Hindi, on Mathematics, entitled *Calan Kalan* i.e. Calculus, and has also compiled a Hindi Grammar.

The *Gaṇaka Taraṅgiṇī* by Dwivedī is on the whole a useful work. From this and from all his other works his profound knowledge of Indian and European mathematics and astronomy becomes evident. Still, he has, at places, passed some baseless and fantastic remarks in the *Gaṇaka Taraṅgiṇī* such as the following :—"Āryabhaṭa introduced the system of denoting numbers, by a new code with a view to keeping secret the numbers of revolutions and other elements which he secured through the favour of some Greek scholar whom he revered as a deity', or 'Bhāskarācārya has described the origin of *jya* at the end of his work, without explaining the underlying theory. It can be surmised from this that he learnt from some Greek traveller only the method and not its theory'. He has the ability to compile a work in Sanskrlt on the lines of the French works, which are being used in compiling the English *Nautical Alamanac*. It is desirable that he should compile one himself.

FURTHER INFORMATION ABOUT AUTHORS AND WORKS BELONGING TO PERIODS PRIOR TO ŚAKA 950

After about 250 pages of the present work were printed, the author came across two or three books not seen before, which contains information about some astronomical works and he proposes to give here extra information collected from them. Mahomed of Ghazni had brought to India a Muslim scholar, named, *ABU AL REHAN MOHOMED BIN AHMED AL BERUṆI.* He was born at Khiva in 973 A. D. He became a Minister to the King of that State. Later on, the province was conquered by *MAHMUD* and *BERUṆI* was brought to India, as a man under surveillance. Beruṇī lived in India from 1017 to 1031 A. D. He wrote a work in Arabic, entitled INDICA, about the year 1031-32 A. D. (i.e. Śaka 953). It contains a description of several sciences

then known in India . Beruṇī had learnt Sanskrit and had studied several works written in Sanskrit. He had paid special attention to astronomy and translated some astronomical works into Arabic. Edward C. Sachau, a Berlin Professor has translated his work, "Indica" into English. It has been published in two volumes. The author gives the information gathered mainly from this work about authors who lived before Śaka 950.

SPREAD OF HINDU ASTRONOMY AMONG MUSLIMS

The Sind province was under the control of the Caliphs of Bāghdād for someyears. During the reign of Caliph *MANSOOR* (753 to 774 A. D.) some ambassadors were sent to his court by the ruler of a State in Sind in 771 A. D. They were accompanied by some astronomers. It was at the hands of these astronomers that some astronomical works in Sanskrit were translated into Arabic. A Hindu astronomer was staying at Bāghdād in 778 A. D. During the reign of Caliph Haroun (786-806 A. D.) also some Hindu works on medicine and astronomy were translated in Arabic. It appears that in those days Brahmagupta's Brahma Siddhānta and Khaṇḍakhādya had already been translated and independent works were compiled in Arabic with the help of different Sanskrit astronomical works.

The Arab astronomers *AL FAZARI*, *YAKUB-BIN-TĀRIQUE*, and *ABU AL HĀSĀN*, lived in the latter half of the 8th century A. D. They compiled astronomical works in Arabic with the help of the Indian astronomers referred to above. These works are not at present available; still Beruṇī had with him the works written by these three astronomers. He has often referred to the works written by the first two. Those works contained several of the following subjects usually found in Sanskrit works, viz. measures of time, numbers of the revolutions of planets in Mahāyuga or Kalpa ; lengths (in yojanas of planetary orbits, calculation of ahargaṇa for finding the mean positions) of planets ; sines of angles ; rising and setting of planets ; first visibility of the moon, etc. The Arabs first learnt astronomy from the Hindus and then they came to know of Ptolemy's work. Al Fazari was the first to teach Hindu astronomy to Mahomedans. The Khaṇḍakhādya had already been translated into Arabic when Yakub compiled his work. That translation may have been made by Al Fazari.

THE PULIŚA SIDDHĀNTA.—

Beruṇī had this Siddhānta with him together with a commentary on it. He was translating it into Arabic. He has given the number of revolutions of planets and those sāvana days in a Mahāyuga, etc., as mentioned by Puliśa, and they agree entirely with those cited by Utpala as belonging to Puliśa Siddhānta. These numbers have been mentioned before (page 18). They do not contain the numbers of the revolutions of Rāhu and moon's apogee which have been given by Beruṇī as 488219 and 232226 respectively. The longitude of the sun's apogee has been stated to be 80°. Beruṇī states that the Puliśa siddhānta describes the yuga system according to the Smṛtis, but it gives 1008 as the number of Mahāyugas in a Kalpa and 14 Manus consisting of 72 Mahāyugas each. The 'twilights' (Sandhyās) and 'semi-twilights' (San

dhyānśas) are, of course, absent, and the Yuga is supposed to begin at midnight. He says "I think that Puliśa siddhānta is the name given after Paulis, the Greek resident of the city of Saintra, and that Saintra is the same as Alexandriā." But he also observes that the Greeks had no yuga system among them. It clearly shows that Utpala's Puliśa siddhānta was widely used at the time of Beruṇī.

*ĀRYABHAṬA I** :—Beruṇī cites the numbers of revolutions of planets given in Abu-al-Hāsān's work and most of these tally with the numbers given by Āryabhaṭa I ; and those that do not differ probably through the errors of copying. Beruṇī had with him some part of the work Āryabhaṭīya and its Arabic translation. This translation must have been made during the reign of Caliph Mansur.

VARĀHA MIHIRA :—Beruṇī has given Śaka 427 as his date. Beruṇī had translated his works Bṛhatsaṃhitā and Laghujātaka into Arabic. The commentary on the *Bṛhajjātaka* by Balabhadra has been referred to by Beruṇī. Sudhākara writes that Varāha's works *Yoga Yatra*' and *Vivāhapaṭal* are available at Vārāṇasī. According to Utpala, there was a work entitled "Samāsa Saṃhitā" by Varāha. It may have been an abridged version of Bṛhatsaṃhitā.

BRAHMAGUPTA :—On the basis of Beruṇī's works, Prof. Sachau observes, "Brahmagupta occupies an important place in the history of oriental culture. Brahmagupta taught astronomy to the Arabs before they came to know of Ptolemy's works, since, references to the works 'Sindhind' and 'Al-Arkand' frequently occur in Arabic literature ; these are the translations of Brahmagupta's works, Brahma Siddhānta and Khaṇḍakhādya". The translations may have been made during the reign of Caliph. Mansur, and it appears from this, that Brahmagupta's works had a wide spread influence in the Sind Province. Beruṇī has repeatedly referred to Balabhadra's commentary on Khaṇḍakhādya. Beruṇī had translated Brahma Siddhānta and Khaṇḍakhādya into Arabic. He observes that the Arabic translations made before his timè were not correct. These translations have not been available so far. Beruṇī had lived mainly in Sind for a good many years. His remarks, at several places, show that Brahmagupta's works had a great influence in that province in those times.

LALLA:—The author of the *Gaṇaka Taraṅgiṇī* also gives Śaka 421 as his date. But it has aready been proved (page 94) that it is wrong. Bhāskarācārya has, in the Golādhyāya, quoted Lalla's verse on the calculation of

* (Beruṇī has referred to the Āryabhaṭa of Kusumpūr and to another Āryabhaṭa who lived earlier. The author could not obtain the work of the older one, but Beruṇī remarks that the Āryabhaṭa of Kusumpūr was his follower. Both of them have been referred to by Beruṇī at 30 places. After reading all those passages, it is found that the description completely applies to the first of the two Aryabhatas formerly described (page 51 and 95) The number of revolutions of planets and such other matters referred to by Beruṇī as to differentiate one from the other very clearly, do not apply to the second Āryabhaṭa, and he was not the follower of the first. From this it follows that the two Āryabhaṭas referred to by Beruṇī are in fact, one and the same person. Even Prof. Sachau, did not note this fact pointed out here. The second Āryabhaṭa who figures in the auhors account, may have lived before Beruṇī, and although it is evident that his work was not seen by Beruṇī, it appears that he laboured under a misunderstanding due to hearsay reports about the existence of two Āryabhaṭa. This leads to the inference that Āryabhaṭa II, may have lived only a century or a half before Śaka 950, and confirms the author's former estimate of his date.,

the area of the surface of a sphere and refuted the method suggested in it. This shows that Lalla may have written a work on arithmetic. Sudhākara says that he may have a work to his credit even on algebra. Beruṇī's works contain something or other by way of description of famous astronomers who tlived before śaka 950; but they do not mention Lalla's name even once. It shows that at least till Śaka 950, Lalla's works were not well known in Sind, Punjab, Kashmir, even the major part of Northern India. From this and from the fact that the first Ārya Siddhānta, as modified by the application of Lalla's cor rections, was in use in the Deccan, he appears to have been a resident of the Deccan.

ŚRĪDHARA :—His work on arithmetic, known as "Triśatikā" *consisting of 300 couplets, is in the Government Library, Vārānasī and it has been remarked in the very beginning of the work :

नत्वा शिवं स्वविरचितपाटया गणितस्य सारमुद्धृत्य । लोकव्यवहाराय प्रवक्ष्यति श्रीधराचार्यः ॥

"Śrīdharācārya, after saluting God Śiva, compiles for the benefit of the public, this work which contains the gist of his (earlier) work on 'Pāṭīgaṇita'.

This means that Śrīdharācārya must have compiled a second work on Arithmetic which was larger than the *Triśatikā*. The *Triśatikā* used many unusual terms like *stambhoddeśa* for *iṣṭakarma* (unitary method), *pratyutpanna*** for *guṇākār* (multiplication) etc. which are different from those used in Līlāvatī. It includes chapters on both arithmetic and mensuration. There is a work named *Nyāyakandali* on logic, and its author's name also is śrīdhara. The work was written in Śaka 913. Authors of works other than astronomical do not generally mention their dates. It appears from this, says Sudhākara, that the author of Triśatikā and Nyāyakandalī is the same one person. Baldeva was the name of the author of Nyāyakandalī and his mother, Abvokā. The village of Bhūrisrṣṭi in the territory of Dakṣiṇarāḍhā was his place of residence.

Bhaṭṭa Śrīdhara compiled the work Nyāyakandalī on the request of Pāṇḍudās. This account, however, is not given in the *Triśatikā* ; and the date of Śrīdhara, the author of Pāṭīgaṇita, as established from the date of Mahāvīra above (page 95) is more reliable than that inferred simply on the basis of the similarity of names. Mahāvīra has quoted Śrīdhara as follows :—

ऋणं धनर्णयोर्वर्गौ मूले स्वर्णे तयोः क्रमात् ॥

It is true that as the line is in 'anuṣṭup' metre it could not have occurred in Trīśati which is compiled in Ārya metre ; still it may have been borrowed from Śrīdhara's larger work on Pāṭīgaṇita or from his algebra. The Aufrecht Catalogue mentions "Triśatigaṇitasāra" as a work by Śrīdhara. It appears from this that Śrīdhara's work *Gaṇitasāra*, procured by Colebrooke and the *Triśatī* mentioned by Sudhākara are one and the same work. There is another work, Jātakapaddhati attributed to Śrīdhara which may have been compiled by Śrīdhara, the author of the *Pāṭīgaṇita*.

* This has been stated chiefly on the basis of the *Gaṇaka Taraṅgiṇī*.

** The term *prtayutpanna* is found in Brahmagupta's works.

BṚHANMĀNASA KARAṆA:—According to Beruṇī, the auhor of this work is Manu, and the work has a commentary by Utpala and it was reproduced in an abridged form under the name of *Laghumānasa* by Munjāl. As the *Laghumānasa* belongs to Śaka 854, Bṛhanmānasa may have been compiled about Śaka 800.

BALABHADRA:—Beruṇī has given several quotations from his works or his commentaries. According to Beruṇī, he had compiled works on each of the sections "Gaṇita, Saṃhitā and Jātaka", and had written commentaries on the *Khaṇḍa Khādya* and the *Bṛhajjātaka*. The work on "gaṇita" has been called a 'tantra' by Beruṇī, which indicates that it advocated the calculation of ahargaṇa from the commencement of Yuga. The quotations given by Beruṇī show that there was also a commentary by Balabhadra on Brahmagupta's Siddhānta. Beruṇī has given quotations from the commentary on the "yoga-śāstra' of Patanjali, and Prof. Sachau infers that the passages were written by Balabhadra as is indicated by the context; and as the major part of the passages is devoted to questions of astronomy, the inference seems to be correct. Balabhadra's works mentioned the latitudes of *Kanauj* and *Sthāneśwar*, which indicates that he may have been a resident of that area. His date appears to be about Śaka 800.

KARAṆASĀRA BY VITTEŚWARA (Śaka 821)

Vitteśwara, son of Bhadatta (or Midhatta) had compiled a work called Karaṇasāra. It has adopted Śaka 821 as the epochal year. According to Beruṇī, Vitteśwara was the resident of Nāgpur. His work mentions 34°-9′ as the latitude of Kashmir ; and it refers to the motion of the Saptarṣīs (the Greater Bear), on which the popular system of reckoning time, currentin Kashmir, is based, and from this I feel that he may have been a resident of Kashmir. The Karaṇasāra described the method of calculating the mean longitudes of planets from the epochal planetary positions given for the moment of the mean Aries Ingress. Beruṇī has given the method (mentioned in the work) of finding the tithi at the moment of mean Aries Ingress (tithi-śuddhi) in terms of degrees, which can be explained if the number of revolutions of the Moon in a Mahāyuga be assumed to be 57753336. This number is given in the Sūrya, Siddhānta the Puliśasiddhānta cited by Utpala, and the First Ārya Siddhānta Beruṇī had with him the Arabic translation of the work made by some one else before his time. The Aufrecht Catalogue does not mention this work at all. From this it seems that it is not available anywhere now. There lived one Vateśwara who was the author of some astronomical works ; and this Vitteśwara mentioned by Beruṇī may have been the same as Vateśwara.

LAGHUMĀNASA BY MUNJĀL (ŚAKA 854):—Munjāl was a resident of the Deccan. He compiled Laghumānasa which was an abridged version of Bṛhanmānasa. Beruṇī observes that it has adopted 6°-50′ as the ayanāṃśa in Śaka 854 and 1′ as the annual rate of precession. From this, according to Munjāl's view, the zero precession year comes to Śaka 444 elapsed. Beruṇī has stated the name of the author to be something like 'Punjāl'. The author of the *Gaṇakataraṅgiṇī* writes, "I have seen Laghumānasa, a short work of 60 verses in 'anuṣṭup' metre. It belongs to Śaka 854. The work does not mention Munjāl's name explicitly, but contains at the end the line 'thus ends (the

work) compiled by Munjāl Bhaṭṭa'. Colebrooke has recorded the dates* of some astronomers as furnished by the astronomers at Ujjayinī, according to which the date of Munjāl is Śaka 854. Bhāskarācārya has given the equinoctial motion as mentioned by Munjāl. This shows that the author of Laghumānasa referred to by Beruṇī, is Munjāl himself. Munīśwara has given, in his commentary called Marīci, the following quotation from Munjāl :—

उत्तरतो याम्यादेशं याम्यांतात्तदनु सौम्यदिग्भागं ।
परिसरतां गगनसदां चलनं किंचिद्भवेदपमे ।।
विषुवदपक्रममंडलसंपाते प्राचि मेषादिः ।
पश्चात्तुलादिग्नयोरपक्रमासंभवः प्रोक्तः ।।
राशित्रयांतरेस्मात्कर्कादिरनुक्रमान्मृगादिश्च ।
तत्र च परमा क्रांतिर्जिनभागमिताथ तत्रैव ।।
निर्दिष्टोथनसंधिश्चलनं तत्रैव संभवति ।
तद्भगणाः कल्पे स्युर्गोरसरसगोंकचंद्र १९९६६९ मिताः ।।

"While the celestial bodies move in the sky from north to south and again from the south to north, a very small variation takes place in their declination.

The (ascending) node in which the celestial equator and the ecliptic intersect is the First point of Aries, Meṣādi and it gives the 'East'. The second node is the first point of Libra (Tulādi), and these two points never change their declination value (which is zero).

The first point of Cancer (Karkādi) is at a distance of three signs (i.e. 90° and after a distance of three signs more, comes the position of the first point of Capricorn (Makarādi). These give the positions of maximum declination which is 24 degrees.

The solsticial points (which mark the junctions of ayana's) show a movement, and the number of their revolutions in a Kalpa is counted as 199669."

These verses are in Āryāmetre, and they mention the number of revolutions of the 'ayana point' during the Kalpa, which is uncalled for in a Karaṇa work. The author of *Gaṇaka Taraṅgiṇī* states that these verses are not found in the copy of Laghumānasa which is composed in 'anuṣṭup' metre. In the beginning of Laghumānasa there are the following lines **:—

प्रकाशादित्यवत्ख्यातो भारद्वाजो द्विजोत्तमः ।। लघुपूर्वं स्फुटोपायं वक्ष्यन्यल्लघुमानसं ।।

"Bharadwāj, the best of Brāhmaṇas was well known like the sun giving light. I compile another Laghumānasa work which would give accurate results."

It appears from this that Munjāl had compiled another work named Mānasakaraṇa. But Beruṇī observes that the author of Bṛhan Mānasa was one Manu. It is not known if the above verse should be interpreted as "Murjāl after compiling a work Laghumānasa, compiled another work

* Essays *Vol.* II, page 461.

** The description of Laghumānasa given hereafter is based on *Gaṇakataraṅgiṇī*. The author of the *Gaṇaka Taraṅgiṇī* has mentioned the date of Laghumānasa, at some places as Śaka 854 and at some others as Śaka 584. The figure 584 is clearly an error due to oversight, as can be seen from the word "Kṛteṣvibha" (854) occurring at two places in the work as Śaka number and from other proofs also.

Laghu laghumānasa (i.e. a shorter version of Laghumānasa than the one existing before)." The above 'āryas' may form Munjāl's second work entitled 'Laghumānasa' or Munjāl himself may have been the author of Bṛhan Mānasa and it might have contained these verses.

The work Laghu Mānasa contains epochal positions of planets true for the noon of Sunday, the first lunar day of the bright half of Caitra, Śaka 854 (elapsed). The planets' places are to be calculated from the ahargaṇa. It contains 8 chapters dealing with the following subjects :— mean places, true places, tithi, three problems, conjunction of planets, solar eclipse, lunar eclipse, and elevation of moon's cusps. The above verse states that Munjāl was a Brāhmaṇa, belonging to Bharadwāj gotra. It is a very important point to note that no available 'human' (pauruṣa) work compiled before Munjāl's time, explicitly mentions the motion of the 'ayana'-point. Munjāl has mentioned a special correction to be applied to the true place of the moon, which is not to be found in any other work. This shows that *Munjāl* was a remarkably ingenious research worker.

The Government Library, Vārāṇasī, has an incomplete copy of Laghumānasa containing solved examples. In these examples, the Śaka year 1494 has been adopted and the 'Dhruvaks' have been given for śaka 1400. The correction due to ascensional difference and other corrections are applicable with respect to the town of Kāmpilya. According to Sudhākara, the author of this commentary may be Parameśwara, the author of the commentary on Āryabhaṭīya, since the statement that "a commentary has been written on Laghu-Bṛhan Mānasa" occurs in the commentary on Āryabhaṭīya. But this is not probable, because, the author thinks that Parameśwar belonged to Mālābar. The above 'example' shows that Laghumānasakaraṇa was in use till Śaka 1500 in some territories.

ĀRYABHAṬA II :—It has already been shown (page 188, footnote) that he lived before Beruṇī.

PṚTHU SWĀMĪ :—Beruṇī writes, "Pṛthudak Swāmī is the author of some astronomical work ; but the name of his work is not known to me." It shows that the commentaries written by Pṛthudak Swāmī were not well known in the times of Beruṇī at least in the Sind Province. Beruṇī has quoted a passage from the work of Āryabhaṭa of Kusumpur to the effect that Pṛthudak Swāmī adopted 120 yojanas as the distance of Kurukṣetra from ujjayinī. Since none of the works of the two Āryabhaṭas mention Pṛthudak's name, it seems that this may have been a passage from a commentary on Āryabhaṭa's works. (It appears at many places that Beruṇī was led to believe that the matter occurring in the commentary, belonged to the original text.). The commentary existed before Beruṇī and Pṛthudak lived earlier than the commentary. From this his date may prove to be somewhat between Śaka 850 to 900.

BHAṬOTPALA :—Beruṇī has mentioned some works of this author in addition to those enumerated by the author (page 101). They are :—The Karaṇaworks—Rāhunnakaraṇa and Karaṇapāta, and a commentary on Bṛhan Mānasa. The names of Karaṇa works appear to be curious and the two Karaṇaworks could not possibly have been compiled by one man. Evidently there was some misunderstanding on the part of Beruṇī. He says that Utpala had compiled another work, Śrūdhava by name ; there seems to be some error in the name of the work. Beruṇī has quoted measures of time

etc. as given in these works. He writes that there were still other works named Śrūdhava. He has given some idea of the questions dealt with in them, which suggest that these may be some works on 'omens' or on horāry astrology.

KARAṆA TILAK BY VIJAYANANDĪ (Śaka 888)

Beruṇī says that Vijayanandī, the commentator, who was a resident of Vārānasī, compiled the work Karaṇa Tilak. Beruṇī has described the methods of calculating ahargaṇa given in the work, the calculation of mean places from ahargaṇa, finding the discs of the Sun and the Moon for calculating eclipses, calculation of Mahāpāta etc. It contains subjects similar to those of the *Graha Lāghava*, the epochal positions given are true for the first lunar day of Caitra Śukla, Śaka 888. Dr. Sehram writes in his notes that the method of calculating the ahargaṇa is similar to that of the Puliśa Siddhānta. Vijayanandī remarks that stars like Dhaniṣṭhā and Uttarābhādrapadā do not set even when they are in proximity to the sun. The Aufrecht Catalogue does not mention this Karaṇa work. It seems that this Karaṇa work is not at present available anywhere. The Vijayanandī referred to by Varāha Mihira was much more ancient than this Vijayanandī.

BHĀNUBHAṬṬA-BHĀNARJU—He has, according to Beruṇī, compiled a 'tantra' work, named Rasāyana Tantra, and a Karaṇa work entitled, Karaṇa paratilak. Prof. Sachau believes that the author's name may be pronounced as Bhānuraja or even as Bhanuyaśa. Varuṇ's commentary on Khaṇḍakhādya (Śaka 962) has borrowed some Anuṣṭup verses, from *Bhānubhaṭṭa's* work and from the work "Tantra Rasāyana". It is not explicitly stated there that he work "Tantra Rasāyana" was compiled by Bhānubhaṭṭa himself, still, the context, shows it to be so ; and hence, the Bhānuraja (Bhānurajju) referred to by Beruṇī and the Bhānubhaṭṭa referred to by Varuṇa appear to be the same person. His date may be about Śaka 900. The Aufrecht Catalogue does not mention either his name or that of his work. It appears from this that the works are probably not available anywhere at present. The word 'tantra' in 'Tantra Rasāyana' suggests that the work had adopted the method of calculating planets' places from the beginning of the Yuga.

OTHER KARAṆA WORKS—After enumerating the names of some Karaṇa works like the Karaṇa Cūḍāmaṇi, Lokānanda Karaṇa by Lokānanda, Bhaṭṭila Karaṇa by Bhaṭṭila etc. Beruṇi winds up the description with the remark that "there are innumerable such works". This statement of Beruṇī supports the inference that have been drawn before (page 120). It was but natural that several Karaṇa works came into existence according to the needs of different times and places. They are not all available at present, and even if they become available, they would be of no actual use. They will, however, be found useful in tracing the history of our country in general and that of astronomy in particular.

OTHER WORKS AND AUTHORS BELONGING TO PERIODS LATER THAN ŚAKA **950** *

ŚRĪPATI :—Munīśwara's commentary on Līlāvatī contains passages from Śripati's works which show that he had compiled works on Pāṭīgaṇita and Bijagaṇita. The following lines occur in those passages :—

दो: कोटि भागरहिताभिहता: खनागचंद्रा १८० स्तदीयचरणोनशरार्कदिग्मि: १०१२५ ।
ते व्यासखंडगुणिता विहृता: फलं तु ज्याभिर्विनापि भवती भुजकोटिजीवे ॥

*This information has been gathered mainly from the *Ganaka Tarangini*.

This describes the method of finding the value of shadow directly from the arcs without making use of tabular sines. Bhāskarācārya has shown the calculation of *chāyā* without sines & arcs. Gaṇeśa Daivajña has succeeded in carrying out all mathematical work in his *Grahalāghava* without the use of sines & arcs. (see pages 133 to 135). This idea, Sudhākara observes, must have occurred to him from Śrīpati's method. According to Sudhākara, Śrīpati had compiled Ratnāvalī and Ratnasāra, as additional Muhūrta works. The Aufrecht Catalogue mentions Ratnasār. This work may have been an abridged edition of Ratnamālā. The compilation of the other work, Ratnāvalī, does not seem very likely since these two works on Muhūrta were already in existence. Perhaps the work Ratnamālā itself may have been called Ratnāvalī by some people.

KEŚAVA :—Keśava, the author of Vivāhavṛndāvana (page127) has stated in that work, in the verse "Tribhāga śeṣe dhruvanāmni" etc. that the 'vyatīpāta' type of 'mahāpāta yoga occurs when the third part of the "Dhruva yoga" is still to pass. This condition was true when the anyanāṃśas were about 12¼°; and in his commentary on the verse Gaṇeśa Daivajña says, "this has been so stated because, the anyanāṃśas at the time of compilation of the work were 12°". This means that Keśava, the writer of the work, Vivāha-vṛndāvana, lived when the ayanāṃśas were 12°, that is, about the Śaka year 1165. The work, in the chapter on Lagnaśuddhi, mentions 4-48 as the *palabhā* of 'Nārmadi' (a city on the bank of the Narmadā). The latitude corresponding to this *palabhā* comes to 21° 48.′ The latitude of Broach, a city situated near the mouth of the Narmadā, is 21°-41′. This shows that his place of residence in those days may have been a town on the bank of the Narmadā.

GRAHA SIDDHI BY MAHĀDEVA :—(page 123). The verses in the work, giving the account of his family which have been quoted by the author of the *Gaṇaka Taraṅgiṇī* are correct. They show that the names of his ancestors, from the father backwards were Paraśurāma, Padmanābha, Mādhava and Jojadeva; and he was a resident of Rasin, near the river Godāvarī. The *palabhā* of the place was 4½. There is a village named Rasin situated to the south of Ahmednagar but its palabhā is only 4 and it is not situated near the Godāvarī but near the river Bhīma, in Mahārāṣṭra. The opening part of the verses giving his family account runs thus :—

ईश्वरकौबेरजजौदाससमस्तज्जजीग्रजन्मासीत् । श्रीजोजदेवनामा गौतमगोत्रः सदैवज्ञः

From this and from some other clues mentioned before (page 124), he appears to be a Gujerati. Though originally a native of Gujerat, he or one of his anscestors may have shifted to Mahārāṣtra.

KĀMADHENU KARAṆA BY MAHĀDEVA :—(Śaka 1289)

Mahādeva, son of Bopadeva, a Brāhmaṇa belonging to Kauṇḍinya gotra residing at Tryambak on the bank of the Godāvarī and enjoying an honorable position at the court, compiled the work, Kāmadhenu, which follows the Brahma pakṣa and Āryapakṣa. It contains 35 verses and tables, and it gives the annual motions and epochal positions of planets. It is claimed that the tithi can be calculated by collecting figures from 22 tables.

GAṄGĀDHARA (Śaka 1356)

In the Kali year 4535 (i.e. Śaka 1356), he compiled a tantra work, named 'Cāndramān.' It follows the modern Sūrya Siddhānta. There is a copy of this work in the Government Library Vārānasī. It explains only the methods of calculating mean and true places of planets. It contains nearly 200 verses. The mean positions in it have been calculated from the number of lunar months. But the solar reckoning too appears to have been included in it. Gaṅgādhara used to reside ir the city of Sagar, situated between the rivers Kṛṣṇāveṇī on one side and Bhīmarathī on the other, both of them lying to the west of Śrī Śaila mountain, which is situated on the prime (Ujjayinī) meridian. He was a Brāhmaṇa, belonging to Jamadagnya gotra. The names of his anscestors, from his father backwards were Candrabhaṭa, Bhaṭṭārya and Viṭṭhal. The astronomer, Śrī Candal, was born in this very family. Gaṅgādhara was a follower of the Sūrya Siddhānta. He was in the good graces of the king of Vidyāpur. As "Candramāna-Tantra" was very difficult to understand, his son Viśwanātha recast the work into easily intelligible verses. Viśwanātha's date is not given.

NṚSIṂHA—Rāma, brother of Gaṇeśa Daivajñya, author of Grahalāghava, had a son, named Nṛsiṃha, (page 139). Rāma may have been a younger brother of Gaṇeśa Daivajñya. Sudhākara writes that this Nṛsiṃha compiled in Śaka 1480, a work entitled "Madhya-graha-siddhi" on the lines of Mahādeva's work "Graha-siddhi". It explains the calculation of the mean places only. The true places are further to be calculated with the help of Mahādeva's work. Kṛṣṇa Śāstrī Godbole observes in his Marāṭhī manuscript : "Nṛsiṃha, son of Rāma and grandson of Keśava Daivajñya. compiled a work entitled Graha Kaumudī in Śaka 1510. The date of birth of Nṛsiṃha is Śaka 1470". One of the two dates, this one and Śaka 1480, mentioned above, must be erroneous. Since Nṛsiṃha says that the planets places should be obtained after multiplying the difference between the given year and Śaka 1480 by the annual motiins, the latter date cannot be wrong. Nṛsiṃha may perhaps have compiled this work some years after Śaka 1480.

CHAPTER 2

THE UNIVERSE

A general description of the Universe has been given in the INTRODUCTION (page XXIX of Part I) Now let the subject be discussed in greater details.

It has already been told (page XXXI of Part I) that the motion of planets in their orbits has been assumed to be the same, and it is about 11858¾ yojanas in one day. And it is also assumed that each planet travels in one Kalpa a length equal to the circumference of the circularring of the celestial sphere. In other words, the length of the celestial orbit* is equal to the sum of the orbital lengths of the revolutions made by each planet in one Kalpa. Hence, the length of a planet's orbit is obtained by dividing the length of the orbit of the celestial sphere by the number of revolutions made by each planet in one Kalpa. The Sūrya Siddhānta gives the measures of orbital lengths as follows :—

*The orbit is really that path in the sky along which a planet appears to revolve round the Earth. The word "celestial orbit," however, does not convey that meaning. As a matter of fact, the celestial orbit has no independent existence. It has been assumed only to facilitate the calculation of the lengths of planetary orbits.

Planet	Orbital length in Yojanas.	Planet	Orbital length in Yojanas.
Moon	324000	Jupiter	51375764
Mercury's mean elongation	1043209	Saturn	127668255
		Starry belt	259890012
Venus's mean elongation	2664637	Celestial sphere (sky)	18712080864000000
Sun	4331500		
Mars	8146909		

MOON'S DISTANCE FROM THE EARTH

All the siddhānta's except the first Ārya-Siddhānta, give the same daily motion, in yojanas, to the planets. Still, as the number of days in the Kalpa vary with each siddhānta, the length of the celestial orbit and those of the planets also differ by a small quantity. It would be of no use to give all these figures, since they contain very little truth. Most of the data are merely imaginary. The moon's orbit, however, has not been determined by imagination. There is a great degree of truth in it. The length of 1′ arc of moon's orbit in its plane, has been assumed to be equal to 15 yojanas by all except Āryabhaṭa I. Hence the length of the complete orbit comes to $(360 \times 60 \times 15) =$ 324000 yojanas; and the mean radius vector of the orbit comes to 51566 yojanas. This is the moon's distance from the Earth. The radius of the Earth, according to the Sūrya Siddhānta, is 800 yojanas; hence, the moon's distance from the Earth is 64·46 times earth's radius. According to modern discoveries it is 50·96 times earth's radius. The distance of the moon from the earth and its orbital length, as determined by the authors of our siddhāntas are so very near the truth that they deserve to be congratulated on having been able to establish such a correct measure.

The motions of planets in their respective orbits have been assumed to be the same and the lengths of orbits are found by dividing the length of the celestial orbit by the number of revolutions of planets in the Kalpa. This amounts to assuming that the times required by planets to revolve in their orbits are proportional to their orbits, that is, to the distances of planets from the Earth. But this is not true according to the modern astronomical theory. The modern theory established by **Kepler** and confirmed by NEWTON and others is that the square of the revolution period of the planet is proportional to the cube of its distance from the Sun.

DISTANCES OF PLANETS FROM THE EARTH

The distance of the Sun from the Earth comes to 689430 yojanas according to the Sūrya Siddhānta, i.e. about 862 times the Earth's radius. But according to modern discoveries, it is about 23300 times the radius of the Earth. The distances of planets farther than the Sun, as given in our siddhāntas, are still

more erroneous. Our astronomers have not determined the lengths of planetary orbits and the periods of their revolutions after first determining the length of the *Celestial orbit* and the mean daily motions of planets in their respective orbits in terms of Yojanas, by actually taking observations. It is quite clear that they first determined the periods of revolutions and the length of the moon's orbit by observation, and then, on the basis of these figures they fixed the lengths of the planetary orbits and that of the circumference of the celestial sphere. The Pañca Siddhāntikā does not mention the lengths of the orbits of planets and that of the circumference of the celestial sphere in terms of yojanas nor does it mention the length of the moon's orbit; it appears, therefore, that the original Sūrya Siddhānta never contained this information. The modern Sūrya Siddhānta does give these measures ; and the author has arrived at the conclusion that the modern Sūrya Siddhānta existed before the Pañcasiddhāntikā. It is not, however, improbable that the lengths of planetary orbits may have been interpolated afterwards*. Secondly all the siddhāntas except the first Ārya Siddhānta have given 15 yojanas as the length of the moon's orbit subtended by one-minute angle. Thirdly the positions of planetary orbits are fixed, and the planets always move through them. The places of the orbits do not change. Hence, the statement that all planets make a revolution of the sky only once in a Kalpa has no meaning. Bhāskarācārya plainly remarks,

ब्रह्मांडमेतन्मितमस्तु नो वा कल्पे ग्रहः क्रामति योजनानि ॥
यावंति पूर्वैरिह तत्प्रमाणं प्रोक्तं खकक्षाख्यमिदं मतं नः ॥३॥

सि. शि. कक्षाध्याय.

"The Universe may or may not be limited by the *Celestial orbit*. It is the writer's opinion that earlier astronomers have defined "the circumference of the celestial orbit" as equal to the total length in yojanas moved through by a planet in a Kalpa."

Our astronomers fixed the lengths of the planetary orbits from that of the moon and the time taken by each planet for making one revolution. The principle, assumed as basis, that the time of a revolution and the length of the orbit are in proportion, was not true, and hence, the measures of orbital lengths have proved to be wrong while the length of the circumference of the *celestial orbit* is found to be utterly fictitious.

Although the measures of orbital lengths and consequently the planetary distances from the centre of the solar system are erroneous, as explained above, still the radii vectors of planets which are their distances from the centre of the solar system, mostly agree with their modern values, when calculated on the basis of the correction known as annual parallax whose values are given in our ancient works and which in fact are the variations affecting their true places as the result of these distances. This will be seen from the subjoined table in which the measures given by

*An ancient work like the Brahma Siddhānta compiled in Śaka 550, does give these measures. Hence, if these measures have found an entry into the Sūrya Siddhānta later, they may have done so very soon after Śaka 550.

*Ptolemy** are also noted :

Planet	Sūrya Siddhānta		Ptolemy	Modern
	even quadrant	odd quadrant		
Sun (or Earth)	1	1	1	1
Mercury	·3694	·3667	·3750	·3871
Venus	·7278	·7222	·7194	·7233
Mars	1·5139	1·5517	1·5190	1·5237
Jupiter	5·1429	5·0000	5·2174	5·2028
Saturn	9·2308	9·0000	9·2308	9·5388

The measures calculated from the Sūrya Siddhānta have been given above. The radii vectors of Mercury and venus are calculated by dividing the length of the circumference of the epicycles of conjunctions** by the lengths of the planetary orbit *i.e.* by 360 and those of the Superior planets by dividing 360 by the circumferences of the epicycles of conjunctions.

It has been remarked above that the length of the moon's orbit according to Āryabhaṭa I is different . It is obtained as follows :

शशिराशयष्ट १२ चक्रं तेंशकलायोजनानिय ३० व ६० अ १० गुणा: ।। ४ ।।

दशगीतिकापाद.

"The length of moon's orbit in yojanas is given by multiplying the total number of signs (*i.e.* 12) by 30, 60 and 10".

In this it is stated that the number of minutes of arcs in the moon's orbit multiplied by 10 gives the length in yojanas. In other words, here 1′ arc is taken to be equal to 10 yojanas, while other siddhāntas have taken it to be equal to 15. This appears to be contradictory to other siddhāntas at first sight , but in fact, there is no contradiction. The following table will show that just as the length of the moon's orbit given in other siddhāntas is 3/2 times that given by Āryabhaṭa I, so also are other measures :—

	Yojanas according to First Āryasiddhānta	Yojanas according to Siddhānta Śiromaṇi
Diameter of the Earth	1050	1581
,, Sun's disc.	4410	6522
,, Moon's disc.	315	480

* Ptolemy's figures have been taken from the translation of the Sūrya Siddhānta by Burgess, and the modern measures from the work of Loomis.

** The lengths of circumferences of the aphelia and the perihelia have been mentioned later on. The question will be discussed at greater length later on in the chapter on true places.

The distance of the moon from the Earth comes to 34377 yojanas, according to the First Ārya Siddhānta. This figure is 65.5 times of 525, which is the Earth's radius according to that Siddhānta. Hence, from a relative point of view there is no cotradiction. The difference in the actual numerical quantities appears to be due to the difference in the measure of the unit, 'Yojana'. Lalla is mostly the follower of Āryabhaṭa I, and hence, measures given by him are Similar to those given by Āryabhaṭa I. Those given by Āryabhaṭa II are like those of other siddhāntas.

EARTH'S RADIUS

A reference to the term "earth's radius'. occurs in the above discussion. Let us give more cosideration to it. Different works mention the diameter of the Earth as follows :—

Name of the work	Earth's semi-diam. (Yojanas)	Name of the work	Earth's semi-diam. (Yojanas)
Pañca Siddhāntikā	$1018\frac{8}{10}$	Brhamagupta S.	1581
Modern S. S. Soma S.	1600	Siddhānta śiromaṇi.	1581
Śākalya—Brahma S.	1600	Vasiṣtha S,	1581
First Ārya Siddhānta, Lalla	1050	Second Ārya S.	2109

WHAT DISTANCE DOES 'YOJANA' INDICATE ?

It cannot be determined with certainty what distance was denoted by 'yojana'. Hence, there is no reliable means to test the accuracy of these dia meters of the earth mentioned in our works. According to the views of most of our works, one Yojana is equal to 32000 cubits, and if one cubit be assumed to be equal to 19·8 inches, the Yojana, in English miles, will be exactly 10 miles. Hence, the diameter of the earth, accepting the lowest figure, that given by the Pañca Siddhāntikā, would be 10186 miles. According to modern astronomy, the diameter of the earth, east to west, is 7925 miles. But the measure of yojana may have been somewhat smaller. The dictionaries known as Vācaspati and Śabdārṇava give 16000 cubits as the length of the yojana, which makes a yojana equal to 5 miles. In the middle of the 7th century A.D. **Hiouen Thsang,** a Chinese traveller, had visited India. He has described the whole of India. He has given distances of cities and places in terms of the Chinese measure, called *Li**. He says, "According to the old system, a yojana consists of 40 *Li* ; according to the current practice of the administration in different parts, a yojana measures 30 *Li* ; but the scientific treatises regard a yojana as equal to 16 *Li* only." According to St. Martin, the measure of one *Li* in China, in the 7th century A.D., was equal to 329 metres *i.e.* 1080 ft. by English measure**.

*Julien's *Memories de Hiouen Thsang I* ; p. 59 ; Translation of the *Sūrya Siddhānta* by Burgess, p. 39.

**Julien's *Memoires de Hiouen Thsang II*, p. 251 ; Translation of the *Sūrya Siddhānta* by Burgess p. 284.

On this basis, the different values of yojana, mentioned by Hiouen Thsang come to $8\frac{1}{6}$, $6\frac{1}{8}$, and $3\frac{1}{3}$ miles. In other words, the measure of a yojana according to current practice in his time was $6\frac{1}{8}$ miles. General Cunningham also compared the distances between several well-known places, given by Hiouen Thsang, with the actual ones, and decided that Hiouen Thsang's 6 *Li* were equal to one mile.* But the distances given by Hiouen are those along roads by which he actually travelled ; and the roads and paths are not always in a straight direction. Hence, in Cunningham's opinion, in order to get the direct distance between two places, distance given by Hiouen Thsang should be reduced by $H\frac{1}{6}$ and Cunningham has done so at several places ; and if this rule be followed, the distence of 6 *Li* given by Hiouen is equal to $(6-\frac{6}{6}=5)$ *Li* in a straight direction ; and thus, the measures given by Cunningham and St. Martin agree with one another. On the whole, the author feels that the unit of yojana equal to 30 *Li* was in use in Hiouen's time, and that while converting his distances into miles, six *Li* must be assumed to be equal to one mile ; in other words, according to the then prevalent system, one yojana was equal to 5 miles. And the diameter of the earth, 1581 yojanas, mentioned by Brahmagupta who lived just before or about the date when Hiouen came to this country in the 7th century A.D., comes to 7905 miles; and this figure is very nearly equal to that of the accurately established modern measure of the diameter.

TO CALCULATE THE DISTANCE IN DEGREES

In any case, the quotations like the following go to prove that our astronomers knew how to measure the distance on the globe equal to one degree and therefrom to calculate the circumference of the earth :—

निरक्षदेशात् क्षितिषोडशांशे भवेदवंती गणितेन यस्मात् ।।
तदंतरं षोडशसंगुणं स्याद्भूमानः ...... ।। १५ ।।

सि. शिरोमणि. भुवनकोश.

"The city of Ujjayinī** lies on the 16th degree $(\frac{360}{16}=22\frac{1}{2})$ of the earth's face, from the "zero-latitude" line. Hence, the circumference of the earth is 16 times the distance between the two places."

It is, however, true that attempts were not made in our country to find out the accurate value of one degree as they were made in Europe.

SUPPORT FOR UNIVERSE

It has been shown before that in the opinion of our astronomers, the earth is at the centre of the Universe ; planets revolve round it and the earth stands suspended supportless in space. But we do not find anything in our works definitely to explain the support for planets. It is, however, their view that the planets and stars are set in motion by the 'pravaha' (provector) wind. It, therefore, seems to be the view of our astronomers that the planets remain in position in the sky, because of the 'pravaha' wind—

निजनिजकर्मविपाकैर्जीवैरुपभुज्यते फलं चित्रं । तद्योगस्थानानि स्वर्गादिकसंज्ञका लोकाः ।। ३ ।।
अनिलाधाराः केचित् केचिल्लोका वसुंधराधाराः ।। वसूधा नान्याधारा तिष्टति गगने
स्वशक्त्यैव ।। ४ ।।

अध्या. १६

* See general description given in the beginning in "Ancient-Geography" by unningham.

**The latitude of Ujjayinī has been determined to be 23°9′ by modern methods.

It is stated in the verse that some worlds remain in position because of the support of the wind. But it is not clearly stated that planets and stars are worlds. It appears that our astronomers did not have the idea that planets and stars are very heavy and expansive globes like our earth.

ATTRACTION

Bhāskarācārya has assumed that the earth possesses the power of attraction. He says,

आकृष्टिशक्तिश्च मही तया यत् खस्थं गुरु स्वाभिमुखं स्वशक्त्या ।।

आकृष्यते तततोव भाति ।। ६ ।।

गोलाध्याय, भुवनकोश,

"The earth possesses the power of attraction. It pulls towards itself a heavy body in the sky and the latter appears to fall."

The falling down of a body is here stated to be due to attraction. When Newton discovered the power of attraction possessed by the earth, what thing other than the falling down of a body to the earth, could have suggested to him the power of attraction possessed by the earth ? He drew the inference that the planetary system revolves round the Sun on account of this power of attraction, and established the law of gravitation, after proving it mathematically ; this further work (of research) was, however, not taken up in our country.

DESCRIPTION OF THE EARTH

All siddhānta works while describing the Universe, give a description of the seven oceans on the earth and seven continents along with mountains and rivers in them ; but this, in fact, forms part of Geography, and hence, the author does not deal with it here for want of space.

VIEWS OF THE SKY

As regards the views of the heavenly bodies observed from different places on the earth, it may be stated that the Pole star appears to be in the horizon when observed from any place on the Equator, and the planets and other celestial bodies appear to rise and set along a vertical circle. As one goes northwards, the north pole appears to attain higher altitudes, and the diurnal circles along which planets and other bodies appear to move, are seen inclined to the horizon. For an observer at the pole, the Sun and other (celestial) bodies, appear to move along circles parallel to the Equator ; all these things are discussed in the Siddhāntas. The author does not give quotations from the original here for want of space.* Again, most of the Siddhāntas discuss questions like these (i) what places in the northern hemisphere (*i. e.* places in what latitudes) can never see a particular portion of the ecliptic, (ii) what latitudes can never see certain signs of the ecliptic or (iii) what are the latitudes where the Sun is visible for 60 ghaṭis or even more, and for how many days . It is not necessary to repeat them here in detail.

* The Marāṭhī book entitled *Bhāskarācārya aṇi tatkāta Jyotiṣa* (Bhāskarācārya & his astronomy) by J. B. Modak contains such quotations from Bhāskarācārya in the original along with their translation.

MERU AND SEVEN WORLDS

They have imagined a mountain called Meru situated at the Pole. Bhāskarācārya has imagined the abodes of Brahmā, Viṣṇu, Maheśa and lords of other worlds, as situated on this very mountain. Similarly, he observes about the seven worlds including the 'bhulok' (earth) as follows :

भूर्लोकाख्यो दक्षिणे व्यक्षदेशात् । तस्मात् सौम्योयं भुवः स्वश्च मेरुः ॥
लभ्यः पुण्यैः खे महः स्याज्जनोऽतो ऽनल्पानल्पैः स्वैस्तपः सत्यमंत्यः ॥ ४३ ॥

भुवनकोश.

It has been told in the verse that the world 'bhūḥ' lies to the south of the zero-latitude line (*i.e.* equator) and the world 'bhuvar' (on which we live) lies to its north. Meru is the "swar" world, and the worlds 'Mahar', 'Jana', 'Tapas' and 'Satyam' are situated in the sky. Of these Satya occupies the last position. Bhāskarācārya says that the description of continents, of seven oceans and of the seven worlds begining with 'bhūḥ' has been borrowed from the Purāṇas. All works do not agree completely as far as this kind of description is concerned.

ATMOSPHERE ENVELOPING EARTH

It is said that the earth is enveloped by a sphere of air which spreads to a distance of 12 Yojanas from the surface of the earth, and the clouds and lightning abide in it. Bhāskarācārya expresses this idea in the line.

भूमेर्बहिर्द्वादशयोजनानि । भूवायुरत्रांबुदविद्युदाद्यं ॥ २ ॥

मध्यगतिवासना.

Both the ĀRYABHAṬAS and LALLA have assumed the same height for the atmospheric covering. 12 yojanas make 60 miles. According to modern discoveries, the height of the atmosphere varies from 45 to 100 miles. Śrīpati has expressed in the following verse the idea that this very atmospheric belt provides a place for whirlwind, meteors, clouds, rainbow, lightning, Gandharva's city and the halo round the Sun and Moon :—

निर्घातोल्काघनसुरधनुर्विद्युदंतः कुवायोः संदृश्यंते खनगरपरीवेषपूर्वं* ॥

PRAVAHA AND OTHER KINDS OF WINDS

LALLA, *SRIPATI* and *BHASKARACARYA* have assumed other kinds of winds higher up than the 'pravaha' wind. Lalla observes :

आवहः प्रवह उद्वहस्तथा संवहः सुपरिपूर्वको वहौ ॥
सप्तमस्तु पवनः परावहः कीर्तितः कुमरुदावहो परैः ॥ १ ॥

धीवृद्धिदतंत्र, ग्रहभ्रमसंस्था.

"There are seven kinds of winds, one above the other in height. They are āvaha, pravaha, udvaha, samvaha, suparivaha, purvakavaha and parāvaha, as the seventh ; others suppose Kumarudavaha, as the seventh wind."

* *Siddhānta Śiromaṇi* edited by Bāpūdeva, p. 267, foot note.

REVOLUTIONS OF PLANETS

The cause of mean motions of planets has already been discussed above. The numbers of the revolutions of planets in the Zodiac during the period of one Kalpa or one Mahāyuga have already been given as mentioned by different siddhāntas. There is a noteworthy point about Mercury and Venus ; and it is that because they are always found near the Sun, their revolutions in the Zodiac are assumed to be always equal to those of the Sun ; and hence, our authors of the works have assumed for them the same number of revolutions and mean motion as for the Sun. But having regarded the conjunction (Śīghra) of Mercury and Venus as some planets, the numbers of their revolutions given by them in the works happen to be equal to those of their actual revolutions round the Sun ; and although our astronomers had no idea that planets revolve round the sun, it is worth remembering that they had given importance to the revolutions of the 'Śīghras' of Mercury and Venus.

LIGHT OF PLANETS

It is the view of our Astronomical science that planets have no light of their own, but that they receive it from the Sun. Āryabhaṭa I observes

भूग्रहभानां गोलार्धानि स्वच्छायया विवर्णानि ॥
अर्धानि यथासारं सूर्याभिमुखानि दीप्यन्ते ॥ ५ ॥

गोलपाद

"Half the spherical portions of the earth, the planets and the stars lose their light in their own shadows. Their faces which are towards the Sun are illuminated in the proportion in which they are so directed."

In this verse it is stated that even the stars receive light from the Sun, which is a mistake. A great deal of discussion is, found in our works regarding the increase or decrease of the Moons' digits, and the elevation of Moon's cusps.

VIKṢEPAS OF PLANETS

The vikṣepas of planets which are the inclinations of their orbits with the ecliptic are given in some siddhāntas in the chapter on mean motions. Therefore, the measures of different siddhāntas are given here—

Ptolemy's values and the modern ones are also given* in this table.

	Modern Sūrya Siddhānta		I Ārya S. Lalla's S.		Brahma S, Sid.Śiro,		II Ārya Siddhānta		Ptolemy		Modern		
	°	′	°	′	°	′	°	′	°	′	°	′	″
Moon	4	30	4	30	4	30	4	30	5	0	5	8	47.9
Mars	1	30	1	30	1	50	1	46	1	0	1	51	2
Mercury	2	0	2	0	2	32	2	18	7	0	7	0	7.[illegible]
Jupiter	1	0	1	0	1	16	1	14	1	30	1	18	41.[illegible]
Venus	2	0	2	0	2	16	2	16	3	30	3	23	34.9
Saturn	2	0	2	0	2	10	2	10	2	30	2	29	39.[illegible]

* The author has taken Ptolemy's values as given by Burgess in his translation of Sūry Siddhānta and the modern values are taken from Leverrier's Tables.

It would not be reasonable to compare the values of vikṣepa as given in our works with the modern ones in all respects. If the comparison is made in a proper way, the discussion which follows will show that our values are very accurate.

The values of vikṣepa are calculated from the latitudes. Latitude is the distance of a planet from the ecliptic measured along the great circle passing through its pole. The latitude is zero at the node ; *i.e.* the point of intersection of the ecliptic and the planet's orbit ; and it is maximum at the point which is 3 signs away from it. The planetary orbits are not exactly circular. So the planets are not always at the same distance from the centre of their orbits. The Moon revolves round the Earth. Hence, when it is at a distance of 3 signs from the node, although her linear distance from the Earth is not always the same, the angular distance is necessarily so. This is not the case with other planets. They revolve round the Sun. The observer at the Sun's centre will always see the maximum latitudes of the planets to be equal to those of the modern values of vikṣepa ; but these will appear to be smaller or greater to an observer on the Earth. The latitude will appear to vary with the values of their radii vectors, *i.e.* their distances from the Sun's centre and their distances from the Earth. The variation due to the first cause is less than that due to the second. Our astronomers have not taken into account the variation due to the first cause. They have only considered that due to the second. Bhāskarācārya remarks about the 'vikṣepa' as follows :—

(यदा) त्रिज्यातुल्य: शीघ्रकर्णो भवति तस्मिन् दिने वेधवलये यावान् परमो विक्षेप
उपलभ्यते तावान् ग्रहस्य परमो मध्यमविक्षेप: ॥

ग्रहछायाविकार, श्लोक १ टीका.

"The maximum value of a planet's mean polar latitude is obtained from the value of the maximum latitude of the planet measured on the circle of observation on the day on which the geocentric radius of the planet is equal to its mean radius vector."

This can be said to be the definition of Vikṣepa according to our ancient works. When the planet is at its mean distance from the earth, it is not necessarily situated at a place 3 signs apart from the node. If the planet is situated 90° away from the node, and its distance from the earth also happens to be equal to its mean value, then the latitude of the planet is regarded by our astronomers as the planet's mean maximum Vikṣepa. This does not take into consideration the factor of planet's radius vector. The latitude of a "superior*" planet is not much affected by the variation in the value of its radius vector but they do cause a difference in the latitudes of "inferior*" planets. Hence, there is no harm if the Vikṣepa values of planets other than Mercury and Venus as given by our works are compared with modern values ; and such a comparison will reveal that our works, as far as the Vikṣepas of

*Marcury and Venus are 'inferior' planets; others are 'superior' ones.

Mars and Jupiter are concerned, have given values nearer to the modern ones than those of Ptolemy. The values given in Brahma Siddhānta and Second Ārya Siddhānta are almost equal to the modern ones. The value for Saturn is wrong by a few minutes only. As regards the Vikṣepa values of Mercury and Venus, it was found that if Mercury occupies at present a position of maximum heliocentric latitude, then, at one position its radius vector attains the value of ·3382 and at the other, ·4114*, and if in addition to this, its distance from the earth has attained the mean value, its true latitude respectively becomes 2°23′′ and 2°53.′ The mean of these values comes to 2°38′ and it agrees very closely with that given in our works. The radius vector of Venus at its position of maximum heliocentric latitude attains the values of ·7193 and ·7293. If at both these positions its distance from the earth attains the mean value, its true latitude would be about 2°28′. This also agrees with the value given in our works. The values given in the table in the column for "modern" values, were calculated by the author from the data in the English *Nautical Almanacs* for the six years 1883 to 1888. It was only on two or three dates during these six years that when Mercury attained maximum value for its heliocentric latitude, its distance from the earth was also equal to or very nearly equal to its mean value ; and in the case of Venus no such dates could be found. It shows that these values cannot be accurately found unless observations are taken for several years ; and for this reason our astronomers deserve praise for having found out very accurate values. The nodes of planetary orbits have got some slight motion. Hence, if the maximum values of the latitudes of planets at the time of Brahmagupta and Āryabhaṭa be calculated in the light of modern mathematics' the above Siddhānta values may perhaps prove to be nearer to the true values** than what we found in this comparison. The above verses will show that the values given by the two Āryabhaṭas are different from those given by Brahmagupta and this shows that the values have been found by them independently. It cannot be argued that the figures are different in the three cases because they have been set down at random. If no other proofs be forthcoming, even the Vikṣepa values given in the above table would be enough to show that our astronomers determined the values for inclusion in their works, actually after taking observations.

CHAPTER III

"AYANA CALANA"

OR

DISPLACEMENT OF SOLSTITIAL POINTS

Even if at a certain time, a star is found to be situated near that point of the ecliptic, which is crossed by the Sun and the Moon while moving from North to South and vice versa, it will not remain there for all time to come ; it will be seen shifting eastwards as years roll by. At the time of the *Vedāṅga Jyotiṣa* the Winter Solstice (W.S.) used to occur near the beginning of Dhaniṣṭha : but as time passed on, it began to take place near Śravana. At

*The mean radius vector of Mercury is ·3871 and that of Venus is ·7233 (Loomis Practical astronomy).

**A mere recording of the values of Vikṣepa as given in our works and the modern ones side by side does not amount to a real comparison. The writer has not seen any one comparing the latitude values of Mercury and Venus as he has done above.

the time of Varāhamihira it used to occur near Uttarāṣāḍha. This means that the solstitial point receded so many degrees. If one point of the ecliptic changes its place, all points on it would necessarily do the same thing. Consequently, the star which at one time would be situated near the equinoctial point, which is the point of intersection of the equator with the ecliptic, would be seen to have shifted its place forward as time would pass ; but in fact, it is the equinoctial point which recedes. As the change in the position of solstitial point was first noticed by astronomers while observing the sun's 'ayana' i.e. the solstitial position, most of the astronomical works have termed this kind of change as "ayana calana". The astronomer ĀRYABHAṬA II and others have mentioned the number of revolutions of the 'ayana,' as if it were a planet. BHĀSKARĀCĀRYA has called this motion also 'Sampāt-calana' i.e. the shifting of equinoxes, while the European astronomers call this phenomenon "precession of the equinoxes". All astronomical works except that of Bhāskarācārya have attributed this motion of solstitial points to the movement of the 'starry wheel'. In other words they thought that the starry wheel moves eastward through some degrees in some particular period of time. But Bhāskarācārya observes :—

तस्य [विषुवत्क्रांतिवलयपातस्य] अपि चलनमस्ति । येऽयनचलन-
भागा: प्रसिद्धास्त एव विलोमगस्य क्रांतिपातस्य भागा: ।।

गोलबंधाधिकार.

"Even that point (viz. the point of intersection of the equator with the ecliptic) has a shifting motion. The equinox recedes through as many degrees as the solstitial points".

This evidently shows that he assumes a retrograde motion for the node (i.e. the equinoctial point) itself. Even the modern European scholars hold that it is the equinoctial point which has this motion of displacement.

MEASURE OF DISPLACEMENT OF SOLSTITIAL POINTS

Varāhamihira has mentioned nothing about the 'ayana-calana' in his Pañca Siddhāntikā. It appears that the five old siddhāntas had mentioned nothing about it. But the modern Sūrya Siddhānta does mention it. It has been described there as follows :—

त्रिंशत् ३० कृत्यो २० युगे भानां चक्रं प्राक् परिलंबते ।। तद्गुणाद्भूदिनैर्भक्तात्
द्युगणाद्यदवाप्यते ।।
तद्दोस्त्रिघ्ना दशाप्तांशा विज्ञेया अयनाभिधा: ।। तत्संस्कृताद् ग्रहात्
क्रांतिछायाचरदलादिकं ।। १० ।।
स्फुष्टं दृक्तुल्यतां गच्छेदयने विषुवद्वये ।। प्राक् चक्रं चलितं हीने छायार्कात्
करणागते ।। ११ ।।
अंतरांशैरथावृत्य पश्चाच्छेषस्तथाधिके ।।

त्रिप्रश्नाधिकार

Meaning :—The 'Starry wheel' (Bhacakra) moves eastwards 600 times during a (Mahā) Yuga. Multiply the Ahargaṇa by 600 and divide the product by the number of mean solar days in a YUGA. Reduce the result to an acute angle ; multiply degrees in this angle falling in one of the four quadrants (i.e. Bhuja) by 3 and divide the product by 10. The result is known as Ayanāṃśa. Calculate the declination, shadow, ascensional difference etc. from the planet's places as corrected by the application of the ayanāṃśa, Whether the 'Wheel' has moved or not can be known on the 4 cardinal days-the solstitial and the equinoctial days. If the longitude of the Sun, as derived from the shadow, is found to be more than that calculated from karaṇa work, it may be taken that the wheel has moved eastward by as many degrees as the difference (of the two), and in case the observed longitude is found to be less than that of the calculated one, the wheel has moved towards the west after returning to its normal position.

This mentions 'triṃśat kṛtyaḥ' i.e. 600 as the number of revolutions of the 'Ayaṇa point' in one Yuga or 600000 during one kalpa. But according to Bhāskarācārya (as stated by him in Golabandhādhikāra, "Tadbhagaṇāḥ sauroktā vyastā ayutatrayam kalpe") "the numbers of revolutions mentioned by the Sūrya Siddhānta are three ayutas i.e. 30000 in one Kalpa or only 30 in one Yuga." This leads one to suspect that the version of S.S. possessed by Bhāskara contained "triṃśat kṛtwaḥ" in place of 'trimśat kṛtyaḥ' as the reading commentators and authors of astronomical works have taken great pains to interpret the words "vyastā ayutatrayam" as meaning something different from 'thirty thousand in reverse direction' in order to reconcile it with the present reading 'triṃśat kṛtyaḥ' in the Sūrya Siddhānta. Munīśwara, the commentator of Siddhānta Śiromaṇi says in his commentary (Marīci) "According to some, the* word 'ayuta' in 'ayutatraya' may be 'niyuta'. According to others, we have to take 20th part of Kalpa and not the actual measure of kalpa, to maintain the relevancy of "600 revolutions per Yuga". Munīśwara himself renders "vyastā ayutatrayam" as "three ayutas multiplied (asta) by vi (i.e. 20), obtaining 60 ayutas as the number." He further observes that the expression "तद्भगणा: सौरोक्ता व्यस्ता अयुतत्रयं कल्पे ।। १७ ।।" गोलबंधाधिकार" may also mean that "the S.S. has mentioned the number of revolutions of this (i.e. the equinox) ; and that another work mentions 'minus three' ayutas as the number of revolutions during a kalpa" ; in other words he does not at all associate the words 'ayutatraya' with S.S. All these are but futile attempts to stretch the words to suit a desired interpretation. Bhāskarācārya's words have been given above. In the commentary on the work he himself remarks, "that the number of revolutions of the equinoctial point is three ayutas in one kalpa has been mentioned in the S.S.". It shows that Bhāskarācārya's remark definitely means that the "S.S. has mentioned 3 ayutas as the number of revolutions in one Kalpa" ; and it appears from this that the S.S., according to Bhāskarācārya, has mentioned 30 revolutions of the equinox during one Mahāyuga.

The verses from S.S. quoted above, show that if the method described here-in be followed, one can never get a figure for ayanāṃśa exceeding 27° ; and since the starry wheel is said to be moving eastward and westward, it

*Nṛisiṃha has remarked thus in the Vasanāārtika The nnmber 3 niyutas in one Kalpa would give 300 in one Mahāyuga.

follows that according to the Sūrya Siddhānta that the equinox does not make a complete revolution through the Zodiac, as the planets do. In other words, the starry wheel moves away from the equinox up to 27° towards the east, then comes to its original position, then moves westward up to 27° and then again comes to the original position. It thus completes an oscillatory revolution, each amounting to 108°. According to modern astronomy the correct motion of the precession of equinoxes is about 50.2 seconds per year. If we adopt a revolution consisting of 108° each and 30 such revolutions per mahāyuga, the annual rate of precession would come to about 2 $\frac{7}{10}$ seconds, which is extremely small. Even if we take 30 true revolutions of 360° each, the annual rate of motion would come to only 9 seconds, which is also very small.. If we take the present reading 'triṃśatkṛtyaḥ' to mean 600 revolutions of 108 degrees per Mahāyuga, it would give 54 seconds per year, and this is now the generally accepted interpretation. This rate is much more correct ; but all current works on astronomy have assumed 60 seconds as the annual rate of motion, and the author has shown later on how this value is the proper one and acceptable. If one takes 600 revolutions of 360 degrees each, the annual rate of precession would come to be 180 seconds. This would be a very excessive rate.

The modern Romaśa, Soma and Śākalyokta Brahma Siddhānta give 600 revolutions of the 'ayana' in one mahāyuga. Their remarks about the displacement of the ayana point are given below :—

द्युगण: षट्शतघ्नोर्कशुद्धोदयहृतो ग्रह: ।। ३१ ।। आयनस्त्रिघ्नतद्दोर्भागा दिग्भिर्विभाजिता: ।।
अयनांशास्तदूध्वार्धे धनं पूर्वदले ऋणं ।। ३२ ।।

रोमशसिद्धांत, स्पष्टाधिकार

इत्येतदेतरप्राक्चलनं युगे तानि च षट्शतं ।। १६६ ।। युक्तयायनग्रहस्तस्मिन् तुलादौ
प्राक् चलं भवेत् ।।

यद्वा तत् शुद्धचक्रे वा मेषादौ प्राक् चलं भवेत् ।। १६७ ।। अयनांशास्तद्भुजांशास्त्रिघ्ना:
संतो दशोद्धृता: ।।

शाकल्यब्रह्मसिद्धांत, अध्या २

युगे षट्शतकृत्वो हि भचक्रं प्राग्विलंबते ।। तद्गुणो भूदिनैर्भक्तो द्युगणोयनखेचर: ।। ३१ ।।
तद्दोर्भुजचक्रदोर्लिप्ता द्विशत्याप्तायनांशका: ।। संस्कार्या जूकमेषादौ केंद्रे स्वर्णं ग्रहे किल ।।३२।।

सोमसिद्धांत—स्पष्टाधिकार

All the three verses convey the same idea as that expressed by Bhāskara. The only point of difference is that in Śākalya's verse the 'ayana-graha' is supposed to move east from the beginning of Libra and towards West from that of Aries.

The Vasiṣṭha Siddhānta (also called Laghu Vasiṣṭha Siddhānta by some) describes the method of calculating Ayanāṃśa as follows :—

अब्दा:खखर्तुभि ६०० भज्यास्तद्दोस्त्रिघ्ना दशोद्धृता: ।। अयनांशा ग्रहे युक्ता.....।। ५५ ।।

स्पष्टाधिकार

"Divide the number of years elapsed by 600, reduce the result to an acute angle nearest to a quadrant, multiply the degrees by 3 and divide by 10, the result thus obtained will be ayanāṃśas.,"

It is not here clear what we get after dividing 'n' years by 600, does the quotient denote so many signs, degrees or revolutions ? If we assume recession through one sign in 600 years, it would give 600 revolutions in a Mahāyuga and that seems to be the number intended.

This shows that the later five Siddhāntas, including S.S., have regarded 27° as the maximum value of ayanāṃśa and that the equinox has been regarded as oscillating from the initial point to 27° East and then back again, till it attains a position 27° West and so on, giving 54 seconds per year as the precessional motion.

Aryabhaṭa I and Lalla make no reference to the ayana-motion in their works. Brahmagupta, while accusing Śrīṣeṇa and Viṣṇucandra, says,

परमाल्पा मिथुनान्ते द्युरात्रिनाड्यो ऽर्कगतिवशादृतवः ॥ नायनयुगं..........॥ ५४ ॥

अध्याय ११

"The very fewest hours of night occur at the end of Mithuna, and the seasons are governed by the Sun's motion ; there is, therefore, no such thing as ayanāṃśa". Pṛthūdaka in his commentary on the above verse says, "What is said by Viṣṇucandra at the beginning of the chapter on the Yuga of the solstice 'Its revolutions through the asterism are here (in the Kalpa) 189411. This is termed a Yuga of the solstice, as of old admitted by Brahma. Arca, and the rest" is wrong. Now the greatest decrease and increase of night and day do not happen when the Sun's place is at the end of the Mithuna ; and passages are remembered expressing "the southern road of the sun was from the middle of Aśleṣā ; and the northern one at the beginning of Dhaniṣthā; and others (of like import). But all this only proves that there is a motion ; not that the solstice has made many revolutions through the asterisms".

Bhāskarācārya while commenting on Brahmagupta's notions about Ayana motion, says :—

तत्कथं ब्रहुमगुप्तादिभिर्निपुणैरपि [क्रांतिपातः] नोक्त इति चेत् तदा स्वल्पत्वात्
तैर्नोपलब्धः ।

इदानीं बहुत्वात् सांप्रतैरुपलब्धः । अतएव तस्य गतिरस्तत्यिवगतं । यद्येवमनुपलब्धोपि
सौरसिद्धांतोक्तत्वादागमप्रामाण्येन भगणपरिध्यादिवत् कथं तैर्नोक्तः· ····

"If doubt be expressed as to how it was that skilled scholars like Brahma gupta and others did not mention the precession of the equinox, the reply is that they could not notice it because of its very small amount. It has been now noticed because of a noticeable displacement and hence, it has now been realised that the equinox has motion. It may be asked, that even though it was not noticed, why was it not given on the authority of the figures mentioned in S.S. just as the numbers of revolutions, Paridhis etc. have been taken from Āgamas." ?

Bhāskara says here, that at the time of Brahmagupta, the ayanaṃs value was very small and hence it is likely that it could not have come to his notice and adds that one may still ask why he did not take the rate of the precession of equinoxes as given by S.S., just as he had taken figures for other measures on the authority of older authors.? It is true that Brahmagupta nowhere mentions any correction on account of precession or gives any figure as the number of yana revolution, yet the above verses of Brahmagupta and Pṛthūdaka's commentary thereon clearly point to the fact that people before the time of Brahmagupta had begun to think over the problem of change in Ayana position. According to Brahmagupta the Sun's entry into a tropical sign was a 'Saṃkramaṇa', and the "end of Sāyana Mithuna" was the Summer Solstice. (This has already been shown in authors' account of his works). Hence he has not at all taken into account the equinoctial motion.

Munjāl's quotations in Āryametre have already been given (H page 191). The number of revolutions of the 'ayana' have been mentioned therein to be 199669. These couplets make no mention of the question whether the equinox makes a complete revolution or not. But assuming that the equinox makes a complete revolution, the explement of the longitude of the equinox would come to $9^s\ 29^\circ\ 37'\ 40''.8$ at the beginning of Kali era, the ayanāṃsa would be zero in Śaka 449, and the annual rate of the precession would be $59''.9007$. All these things clearly point to the fact that Munjāl held the view that the equinox made a complete revolution.

The Laghumānasakaraṇa of Munjāl written in Śaka 854, gives 1′ as the annual motion for precession.

The second Āryasiddhānta gives the revolutions of the ayana planet for Kalpa and describes in the following verse the method of finding ayanāṃśa,

अयनग्रहदो:क्रांतिज्याचापं केंद्रवद्धनर्णं स्यात् ॥
अयनलवास्तत्संस्कृतखेटादयनचरापमलग्नानि ॥ १२ ॥

स्पष्टाधिकार.

Meaning :—"Reduce the longitude of the 'Ayana planet' to an angle less than 1 rt. angle. Find out the sine of the angle. The value is Ayanāṃśa. The sign corresponds to the sign of the 'anomaly'. (It is positive if the Ayana planet be in one of the first six signs, otherwise negative*). After applying this correction to the planet, the values of Ayana Cara (ascensional differences or A.D., Krānti (declination) and Lagna (ascendant) etc. are to be calculated". This is similar to the method of calculating a planet's declination. All our Siddhāntas and even the Second Ārya Siddhanta regard 24° as the maximum value of declination. Hence according to Āryabhaṭa II, the ayanāṃśa value never exceeds 24°. In other words, the "plus" ayanāṃśa figures increases from 0 to 24 degrees, then it diminishes up to zero. It further becomes negative and increases from 0 to 24 degrees, and again begins to diminish till it becomes zero. The equinox is to be supposed to be making a revolution through 96 degrees.

*This convention about positive and negative signs has occurred in connection with planets in this very chapter.

According to the Second Ārya Siddhānta the number of revolutions of Ayana planet during a Kalpa are "masihaṭamudhā*" i.e. 578159. Taking one revolution as equal to 96° the annual rate of precession would come to 46.3 seconds ; but since, the method of calculating ayanāṃśa is exactly like that of calculating declination, the rate of precession will not always be the same. Adopting the above mentioned number of revolutions, the yearly rate of motion of the Ayana planet in the Zodiac would come to 2 min. 53.4 seconds, and the annual rate of precession would sometimes come to 69.4 seconds, sometimes to 6.1 sec. or even less. The Ayana planet takes about 7472 years for one revolution. The rate of precession during the 10th part of the 1st period i.e. during first 187 years, would be 69.4″. During the next 187 years it would be almost the same. In the 3rd period of 187 years it will be 63.7″. It will thus gradually come to be 58.1″, 52″, 43.3″ ; 30.6″, 20.4″ and 6.1″. When thus the ayanāṃśas reach the figure of 24 degrees, they will diminish in value at a reversed rate of motion, they will again increase and will again decrease ; but our experience is otherwise. The ayana-motion no doubt varies ; but the variation is very slight. There is no harm if it be regarded as always constant.

Āryabhaṭa II has, like Parāśara, cited 581709 as the number of ayana revolutions in a Kalpa. According to this hypothesis Śaka 532 would be the Zero-precession year ; and because ayanāṃśas are calculated by the method of calculating declinations, their value is never constant ; their mean value comes to be 46″.5.

Bhāskarācārya has not given the number of revolutions of the equinox in a Kalpa, nor has he given his view** whether the equinoctial point makes a complete cycle or makes an oscillatory cycle of 108°. It has been pointed out above that he has adopted the number of revolutions given in the S.S. He further says,

अयनचलनं यदुक्तं मुंजालाद्यौः स एवायं (क्रांतिपातः) ॥
तत्पक्षे तद्भगणाः कल्पे गोंगर्तुनंदगोचंद्राः १९९६६९ ॥ १८ ॥

गोलबंधाधिकार.

"The displacement of the solstitial point, spoken of by Munjāl and others refers to this very point (viz. equinox). Its revolutions in one Kalpa are 199669.

After quoting the ayana revolutions according to S.S. and Munjāl, in his commentary on the above verse he next observes".

अथ च ये वा ते वा भगणा भवंतु यदा येंशा निपुणैरुपलभ्यंते तदा स एव क्रांतिपातः ।

"Whatever be the number of revolutions, the degrees which are obtained by skilled (astronomers) give the position of the equnox."

It is clear from this that he recommends one to accept the ayanāṃśas which one would actually get by observation at a particular time. Similarly, his remark in this connection that "any motion which one gets actually by observation should be accepted", shows that he means to say that the number of revolutions in a Kalpa should be determined according to the ayanāṃśas actually found. The author has not come across a single statement in which Bhāskarā

*The number has been fixed after fully considering the variations in readings.

**Prof Whitney observes that Bhāskrāchārya has mentioned 199669 as the number of revolutions of the equinox in one Kalpa (See page 104 Trans. of S.S.). But it is a mistake. Bhāskarācārya has given this number as that mentioned by Munjāi.

cārya has clearly said that the equinoctial point makes a complete revolution, nor does he say that it does not make a complete revolution. Bhāskarācārya has taken 1 minute per year as the ayanamotion in the work Karaṇa-kutūhala and has assumed 11° as the ayanāṃśa in Śaka 1105. He thus appears to have taken Śaka 445 as the Zero-precession year, as has been already mentioned before.

From the foregoing discussion of the question of ayana revolution and yearly ayan-motion it can be concluded that according to (*i*) the five Siddhāntas such as the S.S., the annual precessional motion was 54″ (*ii*) Munjāl, 59″.9 (*iii*) Ārya bhaṭa II 46″.3 and (*iv*) Parāśara 46″.5. However, it would not be wrong to say that since Śaka 854, the annual precessional motion was 60 seconds for all practical purposes, and most of the Karaṇa works compiled from that date upto now have given this rate for the ayana motion. The Bhaṭatulya-karaṇa and one or two karaṇa-works following S.S. have, however, adopted 54 seconds as the motion.

Does the Equinoctial Point Oscillate or Revolve ?

The question whether the equinox makes a complete revolution or not has been fully considered above. According to Munjāl, the equinox makes a complete round in the ecliptic in a retrograde direction. As already mentioned Colebrooke says that Pṛthūdaka, the commentator of Brahma Siddhānta, and Nṛsiṃha, that of Śiromaṇi, have quoted Viṣṇucandra, the author of Vasiṣtha Siddhānta, as believing in the theory of the complete revolution of the equinox. According to the five modern Siddhāntas, including the S.S., the equinox does not make a complete revolution but it oscillates upto 27° east and west of Revatī while according to Second Ārya-Siddhānta it oscillates up to 24° only. Although none of the Karaṇa works explicitly states that the equinox makes a complete revolution, the method of calculating ayanāṃśas adopted would give more than 24° or 27°, that is amounts increasing right up to 360°. No karaṇa work probably states that when the ayanāṃśas come to be more than 24° or 27°, the rate of motion should be supposed to be minus 60″, or in other words, the ayanāṃśas should be supposed to be gradually less than 24 or 27 degrees. In accordance with Karaṇa works which assume Śaka 445 as the Zero-precession year and 60″ as the annual rate of precession, the ayanāṃśas would be 24° in Śaka 1885 and 27° in Śaka 2065. They will be 27° in Śaka 2221 if S.S. be followed, and according to Āryabhaṭa II and Parāśara they will be 24° in about Śaka 2400. So the question whether the theory that the displacement of ayana-point does not take place through the whole Zodiac is valid would be settled by actual experience after about 67 years or after 600 years at the most. The modern theory of European astronomers that the equinox makes a complete revolution is a well known fact and if this theory be correct the rainy season will be found to occur in Caitra-Vaiśākha after a lapse of time. No one will be able to deny the contention of the followers of the sāyana system in this respect and the occurrence of spring during the months of Madhu & Mādhava (*i.e.*, Caitra-Vaiśākha) is the only thing acceptable to the Śrutis. Fearing that the acceptance of Munjāl's view would take them into a position contradictory to that approved by the Śrutis, the author of Marīci & others accused Munjāl and others for holding views contrary to the teaching of the Vedas, and they were, in their own way, right in doing so. But it is not within our control to force the equinox to make a complete or incomplete revolution; this point did not strike the author of Marīci and others. The Vedāṅga jyotiṣa has recorded the occurrence of the Winter solstice (W.S.) in the beginning of Dhaniṣṭha. From this it appears that in those days, the equinox used to occur in the beginning of the fourth part of Bharaṇī conste-

lation, *i.e.*, at a point 23° 40″ from the intial point. The Vedas describe the Zodiac as beginning from the Kṛttikās, which suggests that the equinox used to occur in the beginning of Kṛttikās then, *i.e.*, at a point 26° 40″ from the initial point. Formerly the equinox was in advance of Aśvinī, and later on it began to occur behind it. This may have suggested that the equinox oscillates, and because the displacement of equinox which was recorded was only a variation of 24 or 27 degrees, or because the maximum declination is 24°, some of the authors of siddhāntas may have been led to assume that the equinox oscillates up to 24 or 27 degrees. Let, future experience show what it may be, but the theory of oscillation of equinoxes proved very useful in tiding over the temporary difficulty of admitting that the seasons would not conform to the teaching of Śruti as the result of the complete revolution of the equinox.

ACCURACY OF AYANA MOTION

Let us now see how far the annual rate of ayana-motion and the year of zero-precession are accurate, as adopted by our astronomers. The annual ayana-motion is clearly the advance made by the Sun in the assumed length of the year after its two successive transits of the equinox. The lengths of years given by different siddhāntas have been fully discussed on page 13 while reviewing the Romaka Siddhānta of the Pañca Siddhāntikā group. The lengths of year known to Vedāṅga Jyotiṣa, Pitāmaha and Puliśa had already gone out of use before the year Śaka 427 (*i.e.*, before Pañca Sidddhāntikā). It has already been pointed out there that Romaka's year was never in use in our country. Of other Siddhāntas, the length of Brahmagupta's year *viz.*, 365^d, 15^{gh} 30^p $22\frac{1}{2}^v$ does not appear to have remained in use after Śaka 964. The remaining lengths vary from 365^d 15^{gh} 31^p 15^v to 365^d 15^{gh} 31^v 31^g 24^{pv} and have remained in use from Śaka 1000 onwards. The length of the tropical year in the year 1900 A.D. is 365^d-14-31-53-25. This is the time taken by Sun to return to the same equinox. If we deduct this from the length given by S.S. viz. 365-15-31-31-24, the motion of the Sun during the difierence of time would come to 58″.777* or 58″.8 approximately. If we accept the shortest of the lengths of the year in use from 1000 A.D., the annual "ayana-motion" would be less by .269 i.e. about 58″.508. If Brahmagupta's year measure be accepted, it would come to 57″.557 but the author is of opinon** that the above year measure was not taken as the basis while fixing the yearly rate of ayana-motion. It is a fact that the measure of the tropical year is gradually diminishing. If we accept the length of the tropical year in Śaka 700 as basis, all the above-'ayana-motions' will have to be reduced by about 0″·24. All things considered, if the annual rate of precession 58″.4 be accepted, it will be found to be very accurate, since it is in keeping with the average length of the year adopted in our works, and both Grahalāghava and Makaranda which are in use in more than half of India, adopt the length of the year given by moderr S. S. Hence, the rate of precession dependent upon this year length which comes to 58″.6 should be considered accurate. This will show that the figure of 59″.9 adopted by Munjāl as the annual rate of motion and 60″ which is now in general use, appear to be sufficiently accurate.† In other

* Keropant has mentioned 58″.521 (see Planetary Tables page 32,); but a small error seems to have crept in here.

**The reason is given on page 216 later on.

†The difference in the place of the tropical sun computed by European measures and that found from Grahalāghava, is in keeping with the excess of the adopted rate of precession over the calculated rate, *viz.*, 1″.4.

words, our astronomers may be said to have discovered the rate of precession correct within 1″.4 ; and it will be shown later on in the history of the attempts made by other nations to determine the ayana-motion, that our astronomers did not borrow it from others and it is really very creditable to them that they discovered it as a result of their own independent efforts. This alone would suffice to falsify* the arguments of those Europeans who charge Indians with being very backward in the work of taking observations. Even Colebrooke** says that they (Hindus) made a nearer approach to accuracy than he (Ptolemy) had done.

Findings of other Nations Regarding the Rate of Precession

The discovery of the precession of the equinoxes is due to Hipparchus, who arrived at it about the year 125 A.C. by a comparison of his own observations with those of Timocharis, made about 170 years eaelier. Its existence was afterwards established beyond doubt by Ptolemy, nearly 300 years later. Ptolemy mentions, in the seventh chapter of the Syntaxis, that having observed several bright stars in the zodiac he found that they had all increased in longitude to the extent of 2°40′ during the interval of 267 years that elapsed between Hipparchus & himself. He hence inferred that the increase of longitude amounted to 1° in 100 years which implies an annual precession of 36″, he moreover stated that Hipparchus had arrived at the same result. This was a very erroneous determination. The total increase of longitude, during 267 years, must in reality have amounted to 3° 37′, a quantity greater nearly by 1° than that assigned by Ptolemy. As the discordance seems too great to be accounted for by errors of observation, many eminent astronomers have come to the conclusion that Ptolemy made no observations at all, that in fact his catalogue of the stars is no other than the catalogue of Hipparchus reduced to the epoch of 137 A.D. by increasing all the longitudes to the extent of 2° 40′. Unfortunately there are circumstances which strongly tend to justify this serious charge. Delambre compared together the longitudes of the same stars inserted in Flamstead's*** catalogue, and supposing the interval between these two astronomers to comprehend a period of 1553 years, he hence deduced 52″.4 for the annual value of precession. This result exceeds the true value by rather more than 2″. Delambre then diminished Ptolemy's longitudes of the same stars by 2°40′ and supposing the results to be the longitudes of Hippar chus, he instituted a comparison between them and Flamstead's longitudes. Assuming the interval between Hipparchus and Flamstead to include a period of 1820 years, he now obtained 50.″12 for the resulting value of precession, a quantity agreeing almost exactly with the modern determination. (This strengthens the inference that Ptolemy himself had made no observations.)

*At several places in his notes on the translation of S.S. Prof. Whitney has simply poured ridicule on the Hindus in regard to the accuracy of their obseivations.

**Essays, Vol. II, p. 411.

		Birth (A.D.)	Death (A.D.)
***Flamstead :	An English Astronomer . .	1646	1719
Bradley	An English Astronomer . . .	1693	1762
Mayer	A German Astronomer . . .	1723	1762
Lalande	A French Astronomer . . .	1732	1807
Delambre	A French Astronomer . . .	1749	1822
Bessel	A German Astronomer . . .	1784	184

The efforts of modern astronomers have been constantly directed towards obtaining a more accurate value of the precession of the equinoxes. 'Tycho Brahe' fixed the annual precession at 51″ Flamstead made it 50″. Lalande by comparing the longitude of Spica Virginis as assigred by Hipparcus with its longitude deduced from observations made in 1750, obtained 50″.5 for the resulting value of precession. Delambre, by a comparision of the observations of Bradley, Mayer and Lacaille with his own obervations, was induced to fix the annual precession at 50.″1. Bessel who had studied the question very thoroughly fixed the annual value, in 1750 A.D. at 50″.21129. In 1900 A.D. the value for 365½ days will be 50.″2638.

Bessel has fully discussed the precessional motion and determined it to be 50″.21129 in 1750* A.D. The rate of precession in 1900 A.D. will be 50″.2638 in 365¼ days.

In the 11th century **A.D. Arzael, a Spanish astronomer, declared that the rate of precession was about 1° in 75 years i.e. 50″ annually and also that the equinox oscillates east and west up to 10°. Another astrologer, by name Thabit Ben Korrah, (13th Centuty A.D.) held that the equinox oscillated within 22°, and still another astronomer of the 9th century thought that it moved through a circle of radius 4° 18′ 43″. The famous Arab astrotnomer, AL Buṭṭāni (880 A.D.), considered the equinox as oscillating at the rate of 1° in 66 years or about 55.″5*** annually. Some Arab astronomere who lived before the time of AL Buṭṭāni thought the equinox to be oscillatins 8° at the rate of 1° in 80 or 84 years (i.e. about 45″ or 43″ per year). AL Buṭṭāni's figure agrees with that of the S.S.

Accuracy of Zero-precession year

Let us see with what accuracy the years of Zero-precession have been determined by our people. The Zero-precession years according to different astronomical works are given below :—

	Śaka
Five modern siddhāntas including S.S., and Siddhānta Tattwa-viveka	421
Munjāl	449
Rāj Mṛgāṅka, Karaṇa Prakāśa, Karaṇa Kutūhala etc.	445
Karaṇa Kamala Mārtaṇḍa, Graha Lāghava etc.	444
Bhāswatī Karaṇa	450
Karaṇottama	438
Second Ārya Siddhānta	527
Parāśara's view as cited in the 2nd Ārya Siddhānta	532
Dāmodarīya Bhaṭatulya	342

*The information in this paragraph has been taken from Grant's History of Physical Astronomy, pp. 318-20.

**The information in this para has been given on the basis of Colebrooke's essay (*See* Asiatic Researches, Vol. XII, p. 209 et. seq.).

***Rehetsake observes that according to Al Buṭ āni's opinion the equinoctial motion was 1° in 70 years (*i.e.*, 51″.4 annually). (*See* Journal of the Bombay B.R.A.S.. Vol. XI, No. XXXII, Art III. Which of these two views should be taken as reliable ?

The date mentioned in the last work, Bhaṭatulya, has no independent value. The reason is this. Although the author does not mention in clear terms that the ayanāṃśa was zero in Śaka 342, the year can be derived as the initial year from his method of calculating ayanāṃśas and the reason why he adopted that Śaka year as the initial year, is that he compiled the work in Śaka 1339 and adopted 54″ as the annual rate of precession, as given by the S.S. And when Śaka 342 is adopted as the beginning year, the ayanāṃśas in Śaka 1339 come to 14°-57′. If Śaka 444 be adopted as the starting year and 60″ the annual rate, we get 14°-55′, that is, almost the same ayanāṃśa in Śaka 1339. And from this it is evident that because in his time the ayanāṃśas obtained from other works were about 14°-55′, he could not go beyond this value; and he also wanted to adopt 54″ as the annual rate; hence, his zero-precession year comes to Śaka 342. Leaving aside, for the present, the years adopted by the second Ārya siddhānta and Parāśara, let us consider other years. The Zero-precession year according to a siddhānta would be that year in which the moment of the Sun's entry into the first point of Aries, according to that siddhānta, coincides with or occurs very near to the moment of sāyana Aries Ingress. The times of mean & true Aries Ingress in Śaka 450, according to different Siddāntas, were as given below :—

	Mean Aries Ingress (Śaka 450) Caitra S. 14, Monday (20-3-528) (after mean sunrise at Ujjayini)		True* Aries Ingress (Śaka 450) Caitra S. 12, Saturday (18-3-528) (after mean sunrise at Ujjayini)	
	Ghati	Pala	Ghati	Pala
Original Sūrja Siddhānta	45	13·5	34	49
Five modern Siddhāntas	46	38.2	36	14
First Ārya Siddhānta	45	6.2	34	42
Second Arya Siddhānta	47	13·2	36	49
Raj Mrgaṅka. Karaṇa Kutūhala	47	24.6	37	1
Brahmagupta Siddhanta	52	10.8	41	47
	(On caitra S. 13, Sunday)		(On Caitra S. 11, Friday)	

The Sun's tropical longitude **at the moment of the true Aries Ingress according to different Siddhāntas was as given below :—

	Sign	Degree	Min.
Original Sūrya Siddhānta	11	29	58.9
Five modern Siddhāntas	0	0	0.3
First Ārya Siddhānta	11	29	58.8
Second Ārya Siddhānta	0	0	0.9
Rāj Mrgāṅka etc.	0	0	1.1
Brahma Siddhānta	11	29	7.1

* The true Aries Ingress occurs 2d—10gh—15p before the mean according to S. S nd 2d—10gh—24p before mean according to Brahma Siddhānta. The difference of 2d —10gh—24p has through out been taken. It will, however, cause no difference in the result.

**The tropical longitude of the sun has been calculated from Keropant's Planetary Tables. While calculating it, 3 minutes of arc have been adopted as secular equation. In his book Keropant has taken the true Aries Ingress (Nirayaṇa) according to the Sūryā Siddhānta. But the time adopted by him for it is slightly in error. The moment of the true Aries Ingres as actually calculated from S.S. is 51 palas less than that found from Keropant's book.

This shows that Brahmagupta's Saṃkrānti differs much from the Sāyana Saṃkrānti, by about 54 Ghaṭis in Śaka 450, and the year in which both the Saṃkrāntis would coincide comes to Śaka 509 this is so because the length of the year adopted by Brahmagupta is different from that of others. The question of the length of the year has already been discussed in the course of the authors account of Brahmagupta. This point and the moments of the true Aries Ingress given above show that when the Zero-precession year was determined, it was not determined from Brahmagupta's length of the year. The Zero-precession years, that is, the years in which the moment of the true Aries Ingress of the other Siddhāntas coincided with the moment of the Sāyana Aries Ingress, on the basis of their respective year-measures are as follows :—

	Śaka
Five modern Siddhāntas including S.S.	450
Mool Sūrya Siddhānta, First Ārya Siddhānta	451
Second Ārya Siddhānta, Rājmṛgāṅka, etc.	449

This will show that, of the zero-precession years given by different works (page 215), those of Munjāl and Bhāswatī Karaṇa are very accurate. The Śaka year 444 or 445 which is now in use, is also fairly accurate.* The reason why S.S. adopted Śaka 421 as the zero-precession year, in the author's opinion, appears to be as follows :—

According to this Siddhānta, the "Ayana" completes one oscillation in 7200 years; in other words the equinox moves in one direction and returns to its place in 3600 years. It was at the initial point at the begining of Kali-yuga. The period of 3600 years from then terminates in Śaka 421 ; and the true Aries Ingress, according to S.S., occured in that year only about 29 ghaṭis earlier than the Sāyana Aries Ingress ; hence, Śaka 421 was adopted as the Zero-precession year. The work, Karaṇottama, gives 438 as the year but as the author has not seen the work he refrains from offering any comments on it ; still the year is very near to the correct one. According to the method given in the Second Ārya Siddhānta, the year comes to Śaka 527. It has already been pointed out above that as the method of finding the ayanāṃśa is similar to that of finding the declination, the rate of precession is not always the same. The second Ārya Siddhānta was written some time after Śaka 527, when the ayanāṃśas obtainable from other works, those calculated by the method of the second Ārya Siddhānta, and those found by observing the shadow, all the three amounted very nearly to the same quantity and the number of revolutions of the ayana-point was determined on that basis ; and **this is the reason why the Siddhānta gives Śaka 527 as the Zero-precession year. The same thing applies to Parāśara's view cited in the second Ārya-siddhānta. Anyway, the date of zero-precession adopted in our works is beyond doubt fairly accurate. It is the opinion of some that since the junction star of Revatī coincided with the equinox of Śaka 496. according to the accurate modern European methods of calculation, the Zero-precession year must be Śaka 496 ; but it is not justifiable . This question will be discussed later on.

* It is not claimed that the above calculation of the tropical longitude of the sun is extremely accurate. If there be a variation of 1 minute of arc, the zero precession year will also vary by a year.

** Taking this for granted, the date of the compilation of the second Āryasiddhatuā comes to about Śaka 900.

How Ayanamotion and the Date of Zero-precession were Determined

We tested the accuracy of the precessional motion and the date of Zero-precession after comparing them with the tropical longitude of the Sun found from modern European works and the rate of precession determined through accurate investigations of modern times; but we must see how our people determined these things at all. Bhāskarācārya says :—

यस्मिन् दिने सम्यक् प्राच्यां रविरुदितो दृष्टस्तद्विषुवदिनं । तस्मिन् दिने
गणितेन स्फुटो रविः कार्यः ।। तस्य रवेर्मेषादेश्च यदंतरं तेऽयनांशा ज्ञेयाः ।
एवमुत्तरगमने सति । दक्षिणे तु तस्यार्कस्य तुलादेश्चांतरमयनांशाः ।

पाताधिकार, श्लोक २ टीका.

The purport of these lines is that the difference between the calculated longitude of the Sun on the Vernal or Autumnal equinox day and the equinox concerned, is known as Ayanāṃśa. Bhāskarācārya further observes that the difference between the longitude of the Sun on summer or winter solsticial days calculated from siddhānta and allied works and 3 or 9 signs also gives the ayanāṃśa. The Ayanāṃśa should, therefore, be briefly defined as the "difference between the sāyana Sun and calculated Sun." The Sūrya Siddhānta, in the chapter on "three problems" says,

स्फुटं दृक् तुल्यतां गच्छेदयने विषुवद्वये ।। प्राक् चक्रं चलितं हीने छायार्कात् करणागते ।। ११ ।
अंतरांशैरथावृत्य पश्चाच्छेषैस्तथाधिके ।।*

त्रिप्रश्नाधिकार.

The S. S. has, in verses 17 to 19 of the above-mentioned chapter, described the method of calculating Sun's longitude from the length of the shadow and it is indisputable that the longitude so obtained must be tropical (sāyana). Hence, our works define Ayanāṃśa as the difference between the Sāyana Sun and the calculated Sun. And it is evident that by following this method some time after Śaka 445, our astronomers must have found the sun's longitude several times from the shadow and thereby determined first the ayanāṃśa for the date, then the ayana motion and from that the zero-precession year. Observation work must have been carried on for several years for this purpose. It is obvious that the longer the period of observations, the more accurate such results would be.

ASSOCIATION OF THE JUNCTION-STAR OF REVATĪ WITH AYANĀṂŚA-PROBLEM

The above discussion will also show that the junction star of Revatī (Zeta Piscium) has nothing to do with ayanāṃśa or ayana-motion. According to modern astronomy the length of the sidereal year is $365^{d}\ 15^{g}\ 22^{p}\ 53^{vp}$** 13^{vpv}. If that had been the measure of the year adopted by our astronomers, then the junction star of Revatī or some other star assumed to be the initial point of the zodiac, would have had some relation with the ayana motion. In other words, if the junction star of Revatī had been taken to be the initial pointī, then Śaka 496 would have been regarded as the zero-precession year since the equinox was conjoined with that star in Śaka 496, and ayanāṃśa would

*The meaning of this verse has been given (page 207)

**Le Vernier's Tables.

have been defined as the distance of the junction star of Revatī from the equinox. But the length of our year is not equal to that mentioned above, and hence, it cannot with certainty be called a sidereal year. Again, if the junction star of Revatī were taken as the initial point, its longitude ought to have been zero ; but S. S. and Lalla do not take its longitude to be Zero. Āryabhaṭa and Varāha have not given the longitudes of junction stars at all. Brahmagupta and almost all other later astronomers except Lalla regard its longitude as Zero ; but their initial point was not and could never have been near the junction star of Revatī. If we try to find out the year when, according to the modern S. S. the sun, at the moment of the vernal equinox, was near the junction star of Revatī, it comes to Śaka 177 ; and from that date, the position of the initial point of S. S. has been moving east of the junction star of Revatī at the rate of 8″·5 per year.* The year in which the initial point of other works except the Brahma Siddhānta coincided with Revatī and its annual rate of eastward motion, agree with those of S. S. The year in which according to Brahma Siddhānta, the sun was conjoined with the junction star of Revatī at the time of the true vernal equinox, comes to Śaka 598, and his initial point has been moving east of Revatī at the rate of 7″·38 per year. In short, if it be assumed that the year adopted by our astronomers was sidereal and that Revatī was the initial point, the year in which the equinox coincided with Revatī would be the zero-precession year, and the distance of the equinox from this star (in any subsequent year) would be the ayanāṃśa. Theoretically, the argument would be correct ; but it is not borne out by facts. In other words, we would not get the expected results because of a different length of year adopted in our works. Again, the star which is named Zeta Piscium by European astronomers and which has been determined to be the junction star of Revatī by Colebrooke and other European scholars, is a very faint star. The stars have been graded according to their importance and luminosity. Very bright stars like Spica (Citrā), Arcturus (Swatī), Aldebaran (Rohini) are classed as stars of the first magnitude ; Uttarā Anurādhā and some others are of the second magnitude, Kṛttikā & some others are of the third magnitude while Puśyā and some others are of the fourth magnitude i Revati stands between the 4th and 5th magnitude. According to some, it has even been classed as a sixth magnitude star ; there are only 2 or 3 other stars out of 27 which are similar or inferior to it in magnitude. Orhodox astronomers who can point out this star in the sky would rarely be found at present. In short it is such a faint star that there is hardly any possibility of its being used for observation. It is clear from the above (page 218) quotations from S. S. & Bhāskarācārya that it was not used for finding the ayanāṃśa, and wherever methods of taking observation have been described in our works, fixed stars have very little to do with them. The method of converting a planet's place into its sāyana equivalent and then observing it with relation to the equinox or the Sāyana sun appears to have been considerably in use. The author will now show by an example how an error would have occurred in the result, if our astronomers had assumed some relation between Revatī star and precession, that is to say, if they had adopted 50″·2 as yearly ayana motion, which was its displacement from the equinox in one year, and had defined "Ayanāṃśa as its distance from the equinox." The Sun's longitude on Friday the 23rd September 1887, Āśvina S. 7, Śaka 1809, at sunrise according to Grahalāghava, was $5^s\ 7^\circ\ 5'\ 37''$. The ayanāṃśas in this year were $22^\circ\ 45'$. Adding these to the above value, we get $5^s\ 29^\circ\ 50'\ 37''$ as the tropical longitude of the Sun. The Sun thus enters Libra (sāyana)

*The mean Sun moves by so much during the time difference between the length of the year of S. S. and the accurate modern value of the sidereal year.

after about 9 ghaṭis after sunrise and that day ought to be taken as an equinoctial day ; and the Grahalāghava almanac has given 30 ghaṭis as the length of the day on that date. For the same day, Keropant's almanac and Sāyana almanac show 30 ghaṭis as the length of the day. It, therefore, shows that the length of the day given by the Grahalāghava almanac is correct. Now, Keropant's (Patwardhanī) almanac has given 18° 18′ 13″ as the Ayanāṃśa for the date, which is equal to the distance of Revatī from the equinox. Adding this arc to the Sun's longitude as calculated from Grahalāghava, we get 5ˢ 25° 23′ 50″ as the Sun's tropical longitude. This means that the length of the day would be 30 ghaṭis, 4 or 5 days after the 7th lunar day of Āśvina Śukla, which is wrong. We must, therefore, accept the view that our astronomers were quite justified in determining ayanāṃśas on the basis of the difference between the observed longitude and the calculated longitude of the Sun, and the Ayana motion on the basis of these Ayaṇāṃśa figures. it would be proper to change the ayana motion, if the length of the year is changed.

WHEN WAS PRECESSIONAL MOTION FINALLY DETERMINED ?

It is rather difficult to say when the ayana motion was finally determined. The Laghumānas Karaṇa, written in Śaka 854, has given the ayanāṃśas of its time and also 60″ as the ayana motion ; and both these figures are tolerably correct. It is therefore, beyond doubt that before Śaka 800 people had completely understood the ayana motion. The astronomical works written before Śaka 427, such as the original S. S., the First Ārya Siddhānta & the Pañcā Siddhāntikā do not speak of the ayana motionat all. From this it appears that the problem of ayana motion was not considered till Śaka 427. The modern S. S. does mention it and it has been fully discussed on page 206. BRAHMAGUPTA and Lalla who lived after the modern S. S. do not make any mention of the ayana motion while it has been referred to in the S. S. compiled before them. This fact makes one suspect that the verses about the ayana motion in it were interpolated later. The verses in question are given in the chapter on the three problems. As a matter of fact the numbers of the Ayana revolutions ought to have been given along with other numbers of revolutions, in the chapter on mean motions. Again, the correction on account of ayana ought to have been mentioned in the chapter on true places, particularly at the place where the methods for finding declination and 'cara' are described ; but it is not given there. There is, however, a solitary place (verse 6) in Pātādhikāra, where the correction is mentioned, in addition to the chapter on three problems, nowhere else it is mentioned. Further in the Mānādhikāra, the term " Ayana " is applied to the Sun's entry into Capricorn and Cancer. It clearly shows that these verses must have been interpolated later on, because if they are totally removed from the chapter on three problems, one would not feel any hiatres in the continuity of the text. But Bhāskarācārya seems to think that the Ayanacalana referred to by S. S. had been expanded before the time of Brahmagupta (See page 209). As Bhāskarācārya lived 500 years after the date of Brahmagupta, his statement must carry more weight than the inferences of modern students living 1200 years after Brahmagupta. One is thus at liberty to say that the problem of Ayana-Calana must have been under consideration at the time of the modern S. S. as it existed before the time of Brahmagupta. It was, beyond doubt, discussed in Viṣṇu Candra's works which existed before the time of Brahmagupta, about Śaka year 500. It was Brahmagupta's opinion that a Saṃkramaṇa was Sun's entry into a tropical sign and the sāyana " Mithunānta ", (the Sun's exit

from Gemini), the beginning of Dakṣiṇāyana. (This has already been shown in my account of Brahmagupta). Lalla's works make no reference to the ayana motion. It may be due to the fact that either it was his belief that the beginning of Dakṣiṇāyana and the end of Mithuna sign were the same, or else, the difference between the longitude of the calculated and observed (Sāyana) place of the sun was not perceptible in his time. In short, the 'ayana calana' became a problem of study about the year Śaka 500 and that a thorough knowledge of the problem was acquired by Śaka 800.

CHAPTER IV

ON OBSERVATIONS

General Description

The word 'vedha' is derived from the root 'vyadha'. Vedha is the name given to the act of observing the sun or anyother celestial body by holding a rod or a stick or some other object in between. Because the luminous celestial body is 'struck' by the rod, the act of observation has received the name "vedha". The simple casting of a look at a celestial body is termed 'avalokana' (sighting); but this act also can be termed 'observation'. Let us call this kind of observation 'dṛṣṭivedha' (i.e. look). The observation which is taken with the help of a stick or other means of taking observation, commonly known as 'instruments', should be termed 'yantra-vedha' (i.e. instrumental observation).

Our Tradition favours Observation

Europeans say that our people have no knowledge of observation, that our country lacks the tradition of taking observations, and that they have no instruments for taking them ; and they put forth this plea as the main ground for their contention that the Hindus borrowed the science of astronomy from the Greeks. Certainly it cannot at all be said that our people have no liking for observing natural phenomena or that they have no such tendency. This has been proved on the basis of many things pointed out in Part One. Thus the 27 nakṣatras, were known to us even in the dim and distant past, the Vedic times. The Rigveda refers to Saptarṣi stars and the planets. The Yajurveda describes the 27 nakṣatras at great length. In addition to this, the author has pointed out allusions to the constellations known as the pair of divine dogs, the divine boat, and the Prajāpati controlling the nakṣatras. The Taittirīya Saṃhitā narrates a lengthy story about the extreme love of the Moon for Rohiṇī, and the origin of the story is found in the phenomena of the Moon's close conjunction with the star Aldebaran, and the latter's occultation by the Moon, which occurs repeatedly in a period of six years out of every nineteen. The Āśwalāyansūtras allude to Dhruva and Arundhatī. We know of the phenomenon of saturn splitting the car of Rohiṇī 7000 years ago. The Mahābhārata abounds in the description of planets, comets and stars, and the instances have already been cited before. Even the Rāmāyana of Vālmīki refers to the planets and stars at many places. Clusters of stars are mentioned in the Yajñavalkya Smṛti. Our liking for the observation of phenomena becomes evident from these several references occurring in works which are not purely astronomical. Again, there is no doubt that some at least out of the saṃhitās compiled by Garga and others belong to a period prior to that in which our astronomical system was firmly established. They

mainly deal with the question of " grahacāra" i.e. the movements of planets through the nakṣatras. Varāha Mihira has in a long chapter entitled Ketucāra described a good many comets. In the beginning of the chapter, he observes,'

गार्गियं शिखिचारं पाराशरमसितदेवलकृतं च ।। अन्यांश्च बहून् दृष्ट्वा क्रियतेयमनाकुलश्चारः

which means that he was describing the comets on the basis of the descriptions given by Garga, Parāśara, Asit, Deval, and many other sages. The author is giving below some of the quotations from Parāśara and others, cited by Bhaṭotpala in his commentary on the above verse :—

पैतामहश्चलकेतुः पंचवर्षशतं प्रोष्य उदितः ।। ...... अथोद्दालकः श्वेतकेतुर्दशोत्तरं वर्षशतं प्रोष्य...... दृश्यः ।। ......शूलाग्राकारां शिखां दर्शयन् ब्राह्मनक्षत्रमुपसृत्य मनाक् ध्रुवं ब्रह्मराशिं सप्तर्षीन् संस्पृश्य ......काश्यपः श्वेतकेतुः पंचदशं वर्षशतं प्रोष्यैंद्यां पद्मकेतोश्चारांते ...... नभसस्त्रिभागमाक्रम्यापसव्यं निवृत्यार्धप्रदक्षिणजटाकारशिखः स यावंतो मासान् दृश्यते तावद्वर्षाणि सुभिक्षमावहति ।। ...... अथ रश्मिकेतुर्विभावसुजः प्रोष्य शतमावर्तकेतोरूदितश्चारांते कृत्तिकासु धूमशिखः ।।

पराशर.

Purport.—The Paitāmaha comet re-appears after travelling for 500 years (i.e. disappears for 500 years, after it is first seen and then appears againt. The comet named Uddālaka Śvetaketu appears after travelling for 110 years. The comet Kāśyapaśvetaketu whose tail is pointed like a spear, and who, after the disappearance of the comet Padmāketu, first appears in the East, after having travelled for 1500 years, and who, after contacting the Brahma (Abhijit) constellation, the Pole star, the Brahmarāśi* and the Great Bear, traverses the third part of the sky, turns to the left and gives plenty of crops for as many years as the number of months it remains visible in the sky, with its semi-circular tuft of hair. Vibhāvasujaraśmiketu, after having travelled for 100 years, makes its appearance near the Kṛttikā stars after the Āvartaketu. It has a tail of smoke.

Descriptions of many such comets are available. The comets may have received the names Uddālaka, Kāśyapa etc. after the Ṛṣis who discovered and investigated the nature of these comets. This is just like what we find at present in the case of comets such as Enkī's comet, Halley's comet, etc. named after European astronomers ; and these descriptions appear to have been given on the basis of researches traditionally carried on through centuries. The statements of Āryabhaṭa and Brahmagupta that they determined the positions of the Sun and Moon after observing the eclipses have already been given. If the work of taking observations is carried on continuously for several years, it gives useful results ; and it is not possible to do this without royal patronage. Varāhamihira has described how astronomers deserve respect. He has also written that kings should employ astronomers in their service, that some of them should be engaged in the task of taking daily observations of the sky, and that they should distribute amongst themselves different parts of the sky, and then take observations. From this and

* The word Brahmarāśi occurs in Chapter III of Bhīṣmaparva in Bhārata, as can be seen from the extract given in Part I (page 117). It seems from this and also from the above reference, as also from the fact that Brahma was the deity controlling the Abhijit nakṣatra, Brahmarāśi was the name given to cluster of stars around the Abhijit star and the description of the place occupied by the comet agrees with what one may find on the celestial globe. There is nothing impossible in this ; particularly the semicircular shape of the hair (described in the passage) tallies exactly with the position with respect to stars in the sky.

from the astronomical works, Rājamṛgāṅka Karaṇa by King Bhoja, and Karaṇa Kamala Mārtaṇḍa by King Daśabala of Vallabha dynasty which have been mentioned before and from the fact that several authors of astronomical works had the patronage of kings, as can be seen from their own account, it appears that the work of taking observations used to be carried on by royal support. Corrections recommended by different astronomers to be applied to the mean places of planets have been given before at several places. It is evident that these could not have been devised at random. Keśava, for one has described the observations actually taken by him (page 129). KAMALĀKARA the author of Siddhāntatattvaviveka has declared that the pole star has a shifting motion. Even in these days we come across persons who have a liking for observing things. One finds several persons who can correctly point out the planets and several stars even though they have not studied astronomy. Thus two persons who had absolutetly no knowledge of English, Sanskrit and astronomy once casually told that the pole star is not stationary ; and one of them was very fond of observing stars, risings and settings of planets and their conjunctions, and he was very helpful to the author. Once a Vaidic Brāhmaṇa named Pādhye, a resident of Āgāśī, casually met the author in Poona in Śaka 1809. He had not studied any system of astronomy. Still, he chanced to state that, while most of the stars moved from east to west, some stars (those near the North Pole) move in a reverse direction, that is from west to east ; and he told that he came to know of it from his brother Nārayaṇā Janārdan Pādhye. That brother died in Śaka 1795. At that time he was about 22 years old. He was surprisingly intelligent. There may be several such people living. The experiences related here may appear very trivial to some ; but man must have acquired knowledge of astronomy in the initial stages, through the efforts of such persons ; and my object in relating such experiences is to show that the habit still persists among our people. Europeans are surprised to see that while the Saura, Ārya and Brahma siddhāntas mention the numbers of revolutions and other elements of planets, no hint is anywhere given as to how these were calculated and no information of the observations taken has been recorded in them. But they do not take into considaration the conditions in ancient times and the beliefs of our people. In those times when even scripts or any means of writing, not to speak of the printing presses, were not easily available or were even non-existent and all knowledge was preserved by the tradition of being vocally imparted by the teacher to his disciples. Hence, it was but natural that only the siddhāntas which embodied the results of research survived while their sources perished. Again, nobody will now feel astonished if one predicts the time of the occurrence of an eclipse. But in ancient times a man who could predict these phenomena was naturally considered to be superhuman. If he compiled a work, he would naturally incorporate in it only the resulting principles without mentioning their preliminary forms or the means employed in arriving at them. Then in course of time, the work would possibly come to be regarded as 'apauruṣeya' (divine) after the author's name is forgotten & lost ; and once this practice secured a firm footing, the future authors of 'human' works abstained from mentioning the preliminaries leading up to the final results. These were quite probably the reasons why our ancient works lack the information about the observations taken, similar to what we find recorded in Ptolemy's works about his own observations and those taken by Hipparchus, or in the works of later western astronomers. However, some information about the individual efforts made in respect of observations has already been given and some more will be given further on.

DESCRIPTION OF INSTRUMENTS

The instruments for locating the positions of planets and those for measuring time will now be described. The works compiled by Bhāskarācārya are widely known. Hence, it will be of convenient first* to describe the instruments mentioned by him and then to give a brief account of what we find in other works.

GOLA YANTRA
OR
(Armillary Sphere)

A straight round stick of uniform thickness should be taken. It may be called "pole-stick" (dhruva-yaṣṭi). A small spherical ball which can easily slide should be fixed in it, in the centre, to represent the earth, Then a (concentric) sphere to represent the starry sphere should be fixed all round it, It should represent the celestial sphere in which the Sun and other planets are seen to move round the earth. The construction of the starry sphere (bhagol) is as follows :—

Prepare an exactly circular ring**. It should be so tied at two points to the pole stick that it will be divided by those points into two exact parts. A second ring of the same size should be tied to the stick, so that it will cut the stick in those two points, will be perpendicular to (the plane of) the first ring, and will itself be bisected at the two points. These circular rings are called the pair of "standard great circles". Tie a third ring to these rings at four points so that it will be at right angles to them both, and the pole stick will be its axis. This ring is termed '*Nāḍīvalaya or Viṣuvavṛtta*'. Divide this ring into 60 equal parts to represent nāḍīs (or ghaṭikās). A circular ring of equal circumference, called 'Krāntivṛtta' or the ecliptic circle should be tied to the '*equator-circle*' cutting it at two points and inclined to it at an angle of 24°. The Sun moves in this circle. It should be divided into 12 equal parts to represent the signs. If the ball representing the earth be supposed to be a *planet* other than the sun, 'great' circular rings should be tied to the 'ecliptic-circle' at angles equal to the inclinations of the orbital planes of the planets. These also should be marked to show the signs. Then circular rings showing diurnal circles should be tied to the ecliptic circle. While tying the circular rings, care should be taken to see that a portion of the stick is kept projecting and these ends should be passed into two tubes fixed in the celestial sphere whose construction is described later on. The ends of the polestick should point to the poles of the equator, so that the north end of the stick should be found to make an angle, equal to the latitude of the place, with the

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* This description has been given from the chapters on Golabandha and Yantras (istruments). If an attempt be made to describe in detail the instruments along with an explanation of their names, such as Nāḍīvalaya, and other terms, much space will be occupied, and even with all that, it is very difficult to present a description that would enable one to understand them properly without actually seeing them. Hence, only a brief description has been attempted. These however, will help even a layman to understand well the chapters on Golādhyāya and Yantrādhyāya by Bhāskarācārya. If all these instruments are made in the Chhatre memorial scheme, they will prove very useful at a moderate cost.

**Straight, pliable, and soft bamboos have been recommended for preparing these rings. Even those made out of wire will do. These rings themselves represent circumferences of circles.

north pole of the equator lying in the celestial globe which is fixed clearly all round the 'starry sphere'; and the ends of the pole stick should be so passed into tubes that, while the 'khagol' (celestial sphere) would be kept fixed in position, the starry globe would freely rotate in it. The celestial globe should be so set as to envelope the starry globe. Its construction is as follows. Its circular rings should, of course, be larger in size than those of the starry globe. The ring representing the 'samavṛtta' (prime vertical) which passes through the zenith, nāḍir, and the east and west points, similarly the ring representing the meridian, as also the two other rings representing the secondary directions—all these four rings should be of the same circumference. These should be tied to one another, so that each of them would pass above and below the others. The ring representing the plane of the horizon should be tied to them all, midway between them. The north pole should be set above the horizon at an altitude equal to that of the latitude and the south pole at an equal depression below it. Prepare a ring representing the 'Unmaṇḍal' (six o'clock circle) i.e. the great circle which would pass through the east-west points and both the poles which are points in the meridian circle to which the ends of the pole stick in the starry globe are directed. Then tie a 'nāḍivalaya' (celestial-equator-circle) which lies in the plane of the equator of the starry globe and which is larger in size. This should be graduated into ghaṭis. Then fixing nails at the points representing zenith and nādir, another ring should be so fixed in position that it would be free to rotate in a vertical plane with the two nails as the pivots. This is to be called a 'dṛngmaṇḍal' (i.e. the vertical circle for observation). As this is to be rotated inside the celestial glove it should be somewhat smaller in size. A planet is to be observed after so rotating the vertical circle that the planet would be seen in the plane of the observation circle. This celestial globe should be so fitted around the 'starry globe' that the ends of the pole stick could be made to pass through the two tubes fitted on to it. Then after fixing two tubes in the 'khagol' from the outside, another globe called driggola should be fitted on ; and all circular rings like those in the 'khagol' and 'bhagol' should be fixed on to it. This globe is to be constiructed so as to enable one to have a proper understanding of the arcual lines like 'agra' (amplitude) 'kujya' (the radius of the earth) etc., which require the reference to two globes. The whole structure is now Called a 'gola' (i.e. a globe). (Our astronomers sometimes used the term "kṣetra", to denote lines.)

The orbits of planets should, if necessary be tied in this globe separately with circles of aphelia and perihelia. This globe has been described to show the construction of the Universe. In fact it is very difficult to tie together all these rings, and it is still more difficult to take observations with their help. for instance, if the starry globe is fixed inside a 'khagola', it will be difficult to fix the observation circle. It cannot be believed that Bhāskarācārya and others could not realize these difficulties. It is clear that at the time of taking actual observations only the most necessary rings should be made use of, and observation can thus be taken. We had no instrument of the type of astrolabe designed by *Hipparchus ;* but this speaks for the independence of our works in this respect. The above globe can be used in place of the astrolabe, *Brahmagupta*, *Lalla*, and both the Āryabhaṭas have recommended the construction of the same kind of globe. The globe described by the First Āryabhaṭa is less complicated than this.

Bhāskarācārya has mainly described nine kinds of instruments, and their chief use is to find time ; but three of them can be used mainly for taking observations of the celestial bodies. I shall here describe all of them briefly.

1. *The Cakra Yantra* (The disc instrument):—

Procure a disc* of metal or wood. Make a fine hole at its centre. Provide some pivot to the rim of the disc, to which a chain etc. can be attached to support the instrument with. Mark on the disc a line passing through the pivot and the central hole : (this will always remain vertical when the instrument is held suspended in position). Mark on it another line perpendicular to the first line and passing through the centre. Mark graduation lines on the circumference of the disc to indicate degrees. Pass a rod through the hole, perpendicular to the disc. It will serve as an axis. Hold (in hanging position) the disc, with the help of the support before the Sun in a vertical plane, so that the axis will cast a shadow on the disc. The degrees counted from the point in which the shadow cuts the rim to the point in which the horizental line cuts it, will give the altitude of the sun, and the degrees counted from the point to the lowermost point of the disc, will give the zenith distance. (The time of the day can be calculated from this). The same disc may be so held that any two of the 'zero-latitude' stars, Puṣya, Maghā, Śatatārakā and Revatī will be found to be in the plane of the rim. (The disc will thus be held in the plane of the ecliptic). Then the planet will be sighted by moving the eye to and fro, so that the axis would intercept the sight ; the longitude and latitude of planets can thus be found. It is in a way similar to the 'dṛṅmaṇḍal' of the Gola Yantra.

2. *The Cāpa* (Semi circular disc) :—

The half part of the Disc instrument is called a 'Cāpa' instrument.

3. *Turyagola* (Turiya Yantra) :—Half part of the 'Cāpa' instrument *i.e* a 'quadrant' forms a Turiya instrument.

These three instruments are chiefly used in taking observations.

4. The *Gola* instrument (Globe instrument) :—Placing a 'bhagola' in a 'khagola', mark a spot on the ecliptic ring at a place where the sun is expected to be on a particular day. Then so rotate the 'bhagola' that the mark will cut the horizontal circle. Mark that point in the horizon in which the plane of the equator in the 'bhagola' will appear to cut. Then again rotate the 'bhagola' so that the spot marking the Sun's position will cast a shadow on the 'bhugola' *i.e.*, the terrestrial globe. Where the shadow is cast, the number of ghaṭis indicated between the spot and the 'nāḍivalaya' will give the number of ghaṭis elapsed after sunrise on that day. Then the point of the ecliptic in contact with the horizon will give the ascendant at the moment.

5. *The Nāḍivalaya* :—Procure a circular disc. Graduate its rim in ghaṭikās. Pass a rod through its centre perpendicular to the disc. When the rod is held, pointed to the pole, it will cast a shadow on the rim ; and from it the hour angle (natakāl) or its complement can be read. If this very disc is so fitted in a globe that the pole stick will pass through its centre and the terrestrial globe will occupy the central position in it, and if marks indicating ghaṭikās, rising of signs, and the sixfold division of signs (lagna ; horā ; dreṣkāṇa ; navāṃśa ; dwādaśāṃśa & triṃśāṃśa) are made on it, then the shadow cast by the stick will help in finding the time elapsed and the sixfold divisions.

6. *The Ghaṭikā* Instrument :—This is too well known.

7. *The* Śaṅku (Gnomon) :—

Śaṅku is a piece of a round, straight and uniformly thick rod 12 'anguls' in length and having its ends plane and uniform. The chapter on three problems describes methods of finding time etc. from the shadow cast by it.

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*The description will show that it is not a wheel but a disc cut out from a sheet (of metal).

8. *The Phalak* Instrument :—It is an instrument for finding time designed by Bhāskarācārya on the principles of the Cakra Yantra. Its details are not given here for want of space.

9. *Yaṣṭi Yantra* (Pole instrument) :—

Draw a circle with any radius on an even horizontal ground. Mark off principal directions on it and then draw arcs showing 'agrā' (amplitude of the day), both in the East and the West. Draw another concentric circle smaller in size and having a radius equal to "dyujyā " (sky-radius). Mark off points on it to show 60 ghaṭis. Take a stick equal in length to the radius of the outer-circle and hold it pointing to the Sun, with its one end placed at the centre of the circle, so that the stick will cast no shadow. Place in the smaller circle a rod which is equal in length to the distance of the other end of the stick and the end of the amplitude marked in the east. The arc showing ghaṭis intercepted between the ends of the stick will show the time elapsed (in ghaṭis). If the sun is in the West, the distance between the ends will give the number of ghaṭis showing the time left for the day to end. The methods of finding a number of things like 'palabhā', with the help of the 'Yaṣṭiyantra' have been described. Brahmagupta and Lalla have described the method of finding the distance between the Sun and the Moon, and from that the tithi, with the help of a similar but somewhat different type of a 'yaṣṭiyantra'.

Bhāskarācārya has mentioned two other additional self propelled instruments for finding time.

We find in Atharva Jyotiṣa, discussion of the shadow cast by a gnomon, which proves* that the gnomon was known to us before our science of astronomy came in contact with that of the Westerners. The Pañca Siddhāntikā contains a chapter on instruments, which is not quite intelligible ; still it appears that many of the instruments described by Brahmagupta and others were in use in those times. Āryabhaṭa I has not described any instruments at all, but has mentioned a globe as described above. He has, in addition, stated that a globe should be so prepared for finding time that it will automatically rotate with the help of mercury, oil, or water.** Take a wheel. Fix in it somewhat hollow spokes half filled with mercury, with their ends sealed. The wheel will then rotate automatically. Brahmagupta and Bhāskarācārya have mentioned one such automatic instrument. From the globe instrument of Āryabhaṭa described above and from the references in the Pañca Siddhāntikā to some wonders occurring automatically by means of the instruments, it appears that at the time of Varāhamihira there existed such instruments and some other kinds of 'swayaṃ waha' *i.e.*, automatically working instruments. Varāhamihira and Āryabhaṭa have not described the process of construction. Brahmagupta also has described, in addition to the above instruments, some other wonders happening automatically, but has not described their processes.

Instruments of the same type or with certain variations as those described by *Bhāskarācārya* are met with in the works of *Brahmagupta* and *Lalla*. ***But both of them have mentioned some additional instruments for finding time,

*"(3) Atharva Jyotiṣa ",

**Āryabhaṭya, Golapīda, coāuplet No, 22.

***Bhāskarācārya invented a new instrument called the Phalak instrument ; but its origin is to be found in the Cakrayantra itself. Out of the remaining eight, Brahmagupta has not explicitly mentioned the Gola & Nāḍivalaya as seperate instruments. He has, however, mentioned the Golabandha which includes the two. Lalla has not mentioned the Nāḍivalaya out of the eight instruments, but it is included in the Gola itself. It is, however, somewhat surprising that he has not mentioned the Turiya instrument.

viz. Kartarī, Kapāla and Pīṭha. The modern S. S. does not describe any instruments in detail ; still it has mentioned the names of the following instruments :—Swayaṃ-waha, Gola, Śaṅku, Yaṣṭi, Dhanu, Cakra and Kapāla. It is interesting to note that the Pañca Siddhāntikā, Āryabhaṭīya, modern S.S. and Lalla-tantra do not anywhere mention the 'Turiya yantra'.* It was Ptolemy among western astronomers who first invented the quadrant instrument. Before his time, they used the complete circular instrument for taking observations ; but later on, the Western astronomers began to use the quadrant instrument for all purposes. In modern times, however, the quadrant instrument has completely disappeared and the complete circle instruments have come into use in their place. Modern scholars accuse Ptolemy of having taken a retrograde step by introducing the quadrant instrument.** The purpose of mentioning this here is that while the quadrant instrument has been mentioned by Ptolemy, it was not known to our astronomers till śaka 500. It, therefore, proves that the Romaka Siddhānta is neither a translation of Ptolemy's work nor has it been compiled on the basis of that work and that we knew nothing about Ptolemy's work, till at least Śaka 500. The same thing was seen before from our study of the Romaka Siddhānta (Page 12). One more important thing which comes to our notice is that all our instruments have been invented by our astronomers quite independently ; and the quadrant instrument which came into use later on, was also independently invented. It could have been easily suggested by the '*cakra*' and cāpa instruments ; and since it occurs for the first time in Brahmagupta's work, it must have been invented by him.***

The second Āryasiddhānta and modern siddhāntas by Romaśa, śākalya, Brahma, and Soma do not contain the chapter on instruments at all.****

ANCIENT OBSERVATIONS OF WESTERNERS

It would not be irrelevant to say something here about the ancient methods of observations of the Westerners.† The Chaldeans, to whom the origin of astronomy is usually ascribed by European scholars, do not seem to have attained any excellence in this important department of the science. Their observations of eclipses of the moon, as cited by *Ptolemy*†† are as rude as can possibly be imagined. The time is expressed only in hours, and the quantity eclipsed in terms of the half & quarter of the moon's diameter. *Herodotus* states that the Greeks were indebted to the Babylonians for the *pole*, the *gnomon* and the division of the day into twelve hours. The pole seems to have been

*After detecting this omission, the author could not find time for reading the texts of these works minutely, particularly with an eye to the word "turiya". I have, however, gone through all those portions of the works where that word could possibly have occurred and ascertained that it does not occur there.

**Grant's *History of Physical Astronomy*, p. 440.

***The fact that no mention of the 'turiya' instrument has been made in the Sūrya Siddhānta is an additional proof to show that the work was compiled before Brahmagupta's siddhānta.

**** That does not, however, prove that these Siddhāntas were compiled earlier than the Sūrya and other siddhāntas.

†This paragraph has been written on the basis of Grant's *History of Physical Astronomy*, Chapter XVIII.

††Rehatsaik states that the most ancient of these observations are the three eclipses which occurred in the years 719 and 720 B.C. (Jour. B.B.R.A.S. Vol. XI).

a concave hemispherical sun-dial, having a vertical style in the centre, by means of which the interval included between sunrise & sunset was divided into twelve equal parts. It is probable that by the use of the gnomon the Chaldeans succeeded in obtaining an approximation to the length of the solar year, but there is not the smallest reason to suppose that they employed it in determining any other of the fundamental facts of astronomy. Indeed, they do not seem to have made observations at all for the purpose of forming materials to serve as the groundwork of future reasoning. They simply contented themselves with noting the more remarkable phenomena as they occurred, and hence deducing a few rough conclusions of a general nature. It would appear, however, that by comparing together the Chaldean records of eclipses some of the Greek mathematicians ascertained with considerable accuracy several periods relating to the motion of the moon. The earliest astronomical observation recorded as having been made by the Greeks previous to the establishment of the *Alexandrian school*, is a determination of the summer solstice by Meton, in the year 430 A.C. The instrument, termed a heliometer, which was used by *Meton* on this occasion was, in all probability, no other than a modification of the gnomon. The date of this solstice has been chosen for the epoch of the Metonic cycle of nineteen years.* A new era commenced in the history of astronomical observation when *Alexandria* became the capital of the civilized world. Under the liberal patronage of the Ptolemies a magnificent building was erected, in which were deposited circular instruments for determining the positions of the heavenly bodies, and every facility was given to astronomers for prosecuting a continuous series of observations. Timocharis and Aristillus are the earliest individuals mentioned in connexion with this school. These astronomers appear to have flourished about the year 300 A.C. *Ptolemy* (150 A.D.) cites several of their observations. Among these are the declinations of a few of the principal stars and the records of eclipses. It does not appear that they were acquainted with any method for determining the right ascensions of the stars. Eratosthenes (275 B.C. circa) one of the Alexandrian astronomers, determined the obliquity of the ecliptic to be 23° 51′ 19″. It is manifest that neither the distances of the stars from the equator nor the obliquity of the ecliptic could have been determined even roughly without the use of instruments. In treating of the obliquity of the ecliptic, Ptolemy describes an instrument for determining the meridional altitude of the sun. It was composed of two concentric circles, placed exactly in the plane of the meridian, one of which revolved within the other about their common centre. The inner circle carried two small prisms attached to the opposite extremities of a diameter, and when the sun was on the meridian, it was turned round until the shadow of the upper prism fell exactly upon the lower one. An index, affixed to the latter, then marked upon the graduated limb of the outer circle the meridional altitude of the Sun. It was, in all probability, by means of an instrument of this construction that Eratosthenes determined the altitude of the Sun at each of the solstices & hence deduced the obliquity of the ecliptic. Ptolemy cites a passage from Hipparchus which shows that at Alexandria they used to ascertain the passage of the Sun through the equinox by means of a circular ring of metal disposed in the plane of the equator—the shadow of the upper half being watched until it fell upon the inner or concave surface of the lower half. It is not by what means the earlier astronomers

*Meton fixed 6940 as the number of days in a cycle of 19 solar years (Indian Eras by Cunningham, page 43). This makes the length of the year 365d 15gh 47 368pal. Calippus made an improvement in the Metonic cycle by discovering the cycle of 76 years by which the length of the year became exactly 365d—15gh (Indian Eras,p. 43). It is worth noting that none of our astronomical works have adopted these cycles or lengths of year.

determined the declinations of stars. Whatever credit may be due to the earlier astronomers of the Alexandrian school for the sound principles of observation which they appear to have practised, it is to Hipparchus alone that the establishment of astronomy, as a science of calculation based upon observed facts, is to be attributed. He determined the length of the year to be—365d—14g—48p as against the former measure of 365d—15g.

He invented the astrolabe with which he used to find the longitudes and latitudes of celestial bodies. No one before him had a correct knowledge of the sun's apparent motion; and it was he who first compiled tables for calculating sun's true place; these were not known to anyone before him. He recorded observations of the moon, and appears to have compiled tables for finding the true place of the moon. He recorded observations of planets also. The observations recorded by Hipparchus proved useful to Ptolemy in deducing the correction for moon's longitude, called "evection" and to establish the rule for finding the planetary motions. It has already been stated that Hipparchus found the longitudes and latitudes of stars. Ptolemy was not skilled in the work of taking observations. He invented the quadrant instrument. It is nowhere mentioned in clear terms how all these astronomers used to find time. It appears that they used to measure time by the shadow instrument and the clepsydra ('ghaṭi' instrument). Sometimes they used to record what part of the ecliptic was transiting the meridian at the time of taking observations. The Arabs did not bring about any appreciable improvement in the instruments of observation; however, their instruments of observation used to be larger and better than those of the Greeks. The astrolabe used by them was much more complicated.

The above account will show that none of the various lengths of the yeas described so far agrees with those established by our siddhāntas. It hal been proved in the study of the five ancient siddhāntas, that though the origina Romakasiddhānta may have been compiled on the basis of the work of Hipparchus, the Romaka was not the most ancient of our works and that there were works on mathematical astronomy even before the Romaka (page 2).—

Now the author will describe our independent works relating to instruments and observatories :—

SARVATOBHADRA YANTRA :—It appears from two verses quoted by Bhāskarācārya, as from this work, in the chapter on instruments in the Siddhānta Śiromaṇi, that he wrote a work of this name for describing instruments, but as the work is not available, it cannot be described how the instrument was constructed.

YANTRA RĀJA :—There lived in Bhṛgupura an astronomer Madan Sūri by name. His disciple Mahendra Sūri compiled this work in Śaka 1292. There is at the beginning of the work a salutation to ' sarvajña' (i.e. the Knower of all things). From this it appears that this writer must have been a Jain. The work consists of five chapters viz. Gaṇita (mathematics), Yantraghaṭanā (principles of instrument making), Yantra racanā (construction of instruments), Yantrasādhanām (use of instrument), Yantra vicāraṇā (theory of instruments), and has in all 182 verses in it. MALAYENDU SŪRI has written a commentary on it, in which he says that Mahendra Sūri was the Head Astronomer at the Royal Court of Emperor FEROZE SHAH. The Samvat 1435 (Śaka 1300) has been adopted in many of the solved examples. In one case the Samvat 1427

has been taken and in another, Samvat 1447 ; and the commentator calls *Mahendra Sūri* his preceptor, This shows that he (Malayendu Sūri) was his direct disciple ; and the date of compilation of the commentary also was about Śaka 1300. Sudhākara Dwivedī published this work at Vārānasī. The author observes in the very first chapter,

क्लप्तास्तथा बहुविधा यवनैः स्ववाण्यां यंत्रागमा निजनिजप्रतिभाविशेषात् ॥
तान् वारिधीनिव विलोक्य मया सुधावत् तत्सारभूतमखिलं प्रणिगद्यतेत्र ॥

अध्याय १

"The writer is presenting in this work the description of instruments which he has gleaned from various works on instruments written by Yavanas, just as nectar is taken out from ocean."

He has assumed 3600 as the radius and 23° 35′ as the maximum declination; he has given tables of sines, declinations and sky diameters for each degree and has given the length of the shadow cast by a gnomon of seven inches for each degree of altitude, varying from 0° to 90°. The commentator has given the latitudes of about 75 cities. The author of the work has given sāyana longitudes and latitudes of 32 stars which are useful for observation, and has mentioned 54″ per year as the precessional motion. It is not possible to describe the construction of the instrument, Yantra Rāja, briefly, and hence it is not given here. With the help of this instrument the following things can be found directly from observation :—the altitude, zenith distance, longitude and latitude of the Sun ; planets and stars ; distance in degrees between any two celestial bodies, the latitude of a place, the ascending sign and the time and length of the day. There is a commentary on this work written by Yajñeśwara in Śaka 1764.

DHRUVA-BHRAMA-YANTRA :—PADMANĀBHA, son of Nārmada compiled this work. It has already been pointed out (page 126) that the date of this Padmanābha is about Śaka 1320. The work consists of 31 verses and has a commentary written by the author himself. This instrument known as Dhruvabhrama Yantra is meant to find time and it consists of a rectangular plank of wood, the length of which is double the width, and which has a chink bored in it parallel to the shorter edge; the constellation of Dhruva-matsya (polar fish) is to be observed through the chink. The author does not intend to describe here in detail the construction of the instrument meant for finding time. The author has described the "Polar fish"* in the following words :— "There is a cluster of 12 stars round the North Pole. It is called the 'polar fish'. It has two bright stars, one of which is regarded as its mouth and the other as its tail. One of these is on one side of the pole at a distance of 3° and the other lies at a distance of 13° on the other side." The author has described the construction of an instrument by which time can be noted at night by observing the stars situated at the mouth and the tail. A method has been described for finding time by observing other stars at night and even the Sun during the day. Similarly, even the ascendant at any moment is found with the help of this instrument, and it evidently gives the sāyana ascendant. The mean altitudes of junction stars of 28 asterisms at transit as observed in latitude 24° N have been mentioned. It shows that the author may have been the resident of a place whose latitude is 24°.

*See commentary on the 11th verse.

YANTRA CINTĀMAṆI

A mathematician named *Cakradhara,* son of Vāmana, compiled this work and it has a commentary written by the author himself. In addition to this, there is a commentary on the work by Rāma, son of Madhusūdana, a resident of *Pārthapura.* The author has not given his date, but as he has quoted in his commentary some lines from Bhāskarācārya's Siddhānta Śiromaṇi, and Rāma, the commentator, has mentioned Śaka 1547 as the date of his commentary, the work must have been written some time between Śaka 1100 and 1500. His words, " kṣitipālamaulivilasadratna grahajñyāgraṇī cakradharaḥ " meaning " Cakradhara, the leading astronomer, and who is a jewel in the crown of kings " shows that he had the patronage of some king. The work has four chapters containing 26 verses in all. *Dinakara,* son of Ananta belonging to śāṇḍilya gotra wrote a commentary on it with examples in the Śaka year 1767. Yantracintāmaṇi is a kind of quadrant instrument. The observations taken with this instrument give the longitudes of the Sun and the Moon, and also the longitudes and latitudes of five planets, the desired time, and the ascendant true for that momemt, and such other things. The planetary positions and the ascendant are sāyana.

PRATODA YANTRA

Gaṇeśā Daivajña, the author of the *Grahalāghava,* compiled this work on instruments. It contains 13 chapters. The author claims that even while riding a horse one can find time by observation with the help of this Pratoda yantra, and also the shadow cast by the gnomon at that time. Its construction is not described here for want of space. Sakhārāma and Gopinātha have written commentaries on this work.

GOLĀNANDA

This instrument was invented by Cintāmaṇi Dikṣit (page 174). He has written a work entitled *Golānanda* concerning the instrument. It contains 124 verses. It has chapters (*adhikārs*) on the construction of the instrument, mean places, true places, three problems, eclipses, shadow, risings and settings of planets, observations and conjunctions. The following things can be found from observations taken by the Golānanda instrument :— Equation of centre to be applied to planets, planet's distance from the earth, true motion, declinations, ascensional difference, ascendant, directions, amplitude, zenith distance, *valan* (deflections), parallax, *nati* (parallex in latitude), latitude, *dṛkkarma* and the desired time. There is a commentary on the work entitled *Golānandānubhāvikā* by Yajñeśwara.

There may be several such works on instruments. Rāma, the commentator of Yantra Cintāmaṇi, observes :—

विलोकितानि यंत्राणि कृतानि बहुधा बुधैः ।। मतः शिरोमणिस्तेषां यंत्रचिंतामणिर्मम ।।

" I have seen almost all instruments prepared by learned men, and it is my belief that this ' yantracintāmaṇi ' is the best of all." This shows that several kinds of instruments were in use.

The instruments described in Siddhāntaśiromaṇi and other independent instruments mentioned above are rarely seen constructed by any one at present. The gnomon and the quadrant instrument are found at some places. Some instrument by which the time of the day can be found is seen at a number of places.*

OBSERVATORIES

Let us now consider the question ofobservatories. It is evident that if the instruments of observation are permanently fixed they will be found more useful for observation. A building is specially erected for this purpose, and instruments are fixed in it and the work of taking observations is carried on there. Such a place is called '*Vedhaśālā*' (or Observatory). It seems probable that in ancient times in our country such places might have been built under royal patronage and reserved for this purpose ; but we do not anywhere find their description. In some places, stone slabs are found on which lines showing directions are marked. It has been mentioned before, that Cintāmaṇi Dikṣit had such an arrangement for showing directions made at his place of residence in Sātārā. In 1884, the author had gone to Indore for taking part in the Sāyana pañcāṅga controversy. There he learnt that a place had been purposely set apart in the palace area, where lines showing directions have been marked, and astronomers, engaged by the Mahārājā Tukoji Rao, sometimes used to take observations there. The author met an astronomer from Bid who told him that some years ago some instruments had been constructed for the purpose of carrying on the work of taking continuous observations with the help of a party of astronomers maintained by the Moghul Government at Hyderabad ; but the work was later on discontinued. The author has seen astronomers at times taking observations by means of tube instruments. Such attempts on a moderate scale must have always been made in the past, but we have at present a reliable information about only one attempt of this kind made on a very big scale. It is as follows :—Jaya Siṁha (page 169) built five observatories. The author is giving below, an extract** from the introduction to his own works

*While this chapter was being printed (during the months of Vaiśākha and Jyeṣṭha of Śaka 1818) Mr. Naraso Gaṇeśa Bhānu, a resident of Mirāj, sent to the author some papers on which he had copied out diagrams of some of the instruments. Bhānu is not an astronomer. He is at present a pensioner of the Mirāj State, still, he has a great liking for this subject. The original instruments of which these were the copies were constructed by one Sakhārāma Jośī, a resident of Koḍolī near Kolhapur, between Śaka 1712 and 1718. Of these, some were probably made of cast brass, as stated by Bhānu. They include *grades of some* instruments and 'turya yantra', 'phalak yantra' 'dhruvabhramana yantra' and other instruments. One kind of Yantrarāj instrument was constructed at Saptarṣi (Sātārā) in Śaka 1712 ; it has marked on its dial 17° 42′ as the latitude of Sātārā, and the altitudes of junction stars of 27 asterisms and of some other stars at the times of transit, along with their directions ; e.g. the altitude of Maghā has been given as 83° 57′ South. Another Yantrarāj has been constructed for Karavīr (or Koḍolī) in Śaka 1718. It has marked on it 17° 21′ as the latitude of Karavīr (Koḍolī) and the altitude of Maghā as 84° 15′ South. According to modern astronomy, the latitude of Sātārā is 17° 41′ and that of Kolhapur 16° 41′, and in Śaka 1718, the declination of the junction star of Maghā was about 12° North ; and the transit altitudes of the star were 84° 19′ at Sātārā and 85° 19′ at Kolhapur. Anyway, Sakhārāma Jośī appears to have been very painstaking. The above-mentioned instruments are at present with his great grandson Sakhārāma Śāstrī at Kadeguddi near Belgaum in the Sāhāpur Taluka. His another great grandson Moraśāstrī lives at Miraj, and he has also some instruments with him.

**This extract has been taken from an article by the well known scholar, William Hunter, published in Asiatic Researches, Vol. V, pp. 177-211.

KSIZ MOHOMED by name. It will give a complete idia about his efforts :— "so incapable are human beings of comprehending the powers of the Almighty that Hipparchus can be said to be simply a rustic, and Ptolemy only a swallow. The theorems of Euclid are but an imperfect form of divine work. Similar by, thousands of people like Jamsedkasī and Nasīrtusī, have laboured in vain and became fatigued. The calculations made from works on astronomy like those of Sayad Gurganī and Khayānī, the Ākbarśāhī work of Inśil-al-Mulācand and astronomical works of Hindu writers as also those of European writers, do not agree with observed phenomena ; especially, the new moon's appearance, risings and settings of planets, eclipses and conjunctions of planets do not agree with observation at all. When this fact was told to Emperor Mohomadśāhā†, he asked him (*i.e.* Jaya Siṃha) to decide the matter. He erected at Delhi instruments like those erected by Mirzā Ulugbeg at Samarkand................Jaya Siṃha found that his ideas about the correctness of results could not be realized by brass instruments, because the instruments were small, not convenient for showing minutes of arc, their axes shift their places and get worn out ; the centres of circular plates also shift their places and the planes of instruments get twisted. He thought these to be the reasons why the calculations of Hipparchus and Ptolemy did not tally with observed results. He, therefore, erected the Jaya Prakāś, the Rāma, and the Samrāt instruments which were perfectly stable and built in mortar and stone, whose semi-diameters were 18 cubits, and one grain (yava) in the circumference of which would represent 1 minute of arc. These were constructed and erected with due consideration of geometrical theory, the meridian,and latitude of the place and with careful measurements. They were so designed that it wold be possible to repair the defects caused by the sinking of circular planes, wearing out of axes, shifing of the central points, and irregular spacing of minute divisions. An observatory of this type was built at Delhi. Corrections to be applied to mean motions of planets, which never agreed with observation, were finally determined on the basis of observations taken with these instruments. In order to test the correctness of results of observations taken at the Delhi observatory, he erected similar observatories at Sawai, Jaipur, Mathura, Vāranasī and Ujjayinī. Observations taken at all these places tallied with one another. After seven years were spent in taking these observations, it was learnt that similar work was being done in Europe also. Hence, MANUEL, the priest and some other scholars were sent there and the planetary tables compiled 30 years ago and published in the name of *LIEL**, were brought through them. The calculations made from them, however, did not agree with observations; it was found that there was an error of about 1/2 degree and some perceptible etror in the case of other planets. Hence, under the direction of the Emperor, a work was compiled containing formulae and mathematical processes for calculation, which were very precise and correct. Its calculation exactly tallies with observation. (The emperor's name was given to the work as a mark of honour.)"

HUNTER, visited four out of the five observatories about the year 1799 A. D. and wrote their description in the "Asiatic Researches" mentioned above. It is not given in full for want of space. The description of the observatory at Vārānasī, as given by Sherring (1868 A. D.) in his English book

†He was on the throne at Delhi from 1720 to 1748 A. D.

*Jayasiṃha completed the compilation of his work in 1141 Hijrī era (i.e. 1728 A.D or Saka 1650). The work brought from Europe was of De Levarrior. It was first published in 1678 A. D. and then again in 1702 A. D.

on the city of Vārānasī, is given here, the description* being based on an article by Paṇḍit Bāpūdeva on "Instruments located in the Māṇa Mandira", (Other observatories are constructed on the same plan.) :—This observatory is situated on the bank of the Ganges at a spot known as Māna Mandira† Ghat. It is known as 'Māna Mandira'. This building and the whole locality is at present in the possession of the Mahārājā of Jaipur. The observatory building is quite firm and strong. After ascending the steps on the outside, one enters into the square. After crossing it through, one reaches a staircase which leads to the main part of the observatory. Some of the instruments in the observatory are very huge in size. This structure is likely to last for thousands for years very easily. Still, they are so delicate that they could give very accurate results as desired by the original constructor of these instruments. A Brāhmaṇā is appointed to look after its upkeep ; but it has not been maintained by him in a good condition. The instruments are getting damaged on account of heat and rain ; and their parts and subdivisions, being worn out, are vanishing awaya. After entering the observatory, one sees the 'wall instrument' (Bhitti Yantra). It is a wall 11 ft. high and 9 ft. 1¼" long, built in south-to-north direction. With the help of this instrument, the altitudes and zenith distances of the noonday sun, its maximum declination and the latitude of the place can be found. There are two large circular structures near, one is made in stone and the other in mortar ; and there is also a square structure made of stone. This might have been used for finding the shadow of the gnomon and the azimuth. But all the marks on them are now obliterated. There is a very big instrument known as Yantra Samrāt (the emperor of instruments). This is another wall 36 ft. long and 4½'ft. thick and build in the south-north direction. One end of the wall is 6 ft. 4¼" high and the other is 22 ft. 3½" high ; and this wall is gradually elevated towards the north so that the pole star is visible in the plane. With the helf of this instrument, the meridian distance, declination and right ascension of celestial bodies can be found. There is another double wall instrument here. To its east is erected a Nāḍi Valaya instrument made of stone. There is similarly another small model of the Yantra 'Samrāt instrument. Near to it is a Cakra-Yantra fitted between two walls. It was used for finding the declinations of stars ; but at present it is nor in good condition. There is a huge Digaṃśa instrument near it. It was used for finding the azimuths of stars. It consists of a pillar 4 ft. 2" high and 3 ft. 7½" wide. There is another concentric wall having double its height and build at a distance of 7 ft. 3¼" from it. The top surfaces of both the walls are graduated in 360° and directions are noted on them ; there is another Nāḍivalaya instrument to its south, but the marks on it are obliterated.

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*The author could not procure Bāpūdeva's original work in spite of great efforts.

†I think that the place may have received the name Māna Mandira because it was the place where the measures (Mān) like the motions of planets used to be found out.

(2) ADHIKĀRA ON TRUE PLACES

Chapter 1

True places and motions of planets

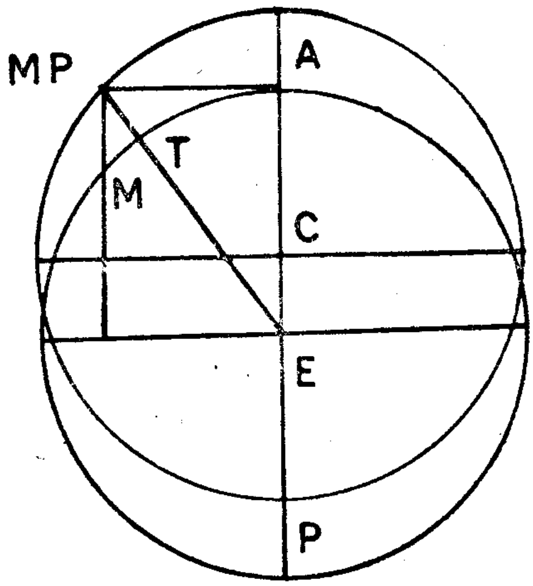
A planet is not found moving every day at its mean daily rate of motion which is obtained from the time it takes to make a complete revolution through the Zodiac, but at a greater or smaller rate ; and hence, on a given day it is not seen actually occupying the place in the sky which is found from its mean motion by calculation. The position and motion of a planet as actually seen in the sky are called its true (spaṣṭa) place and motion. It is the subject of study for the chapter on true places to find the true position and motion of a planet from its calculated mean position and motion. [It is a convention with our w rks to speak of the true position of a planet as "true planet" (spaṣṭa graha) and hence, this term is so used in some places in the following discussion.]

The chief reason why the true motions of the Sun and Moon differ from their mean motions is that according to the laws of planetary motions, which are now almost universally recognized, and which were first discovered by *Copernicus*, and verified and firmly established by *Kepler* and *Newton*, the earth revolves round the Sun, and the Moon round the earth in an elliptical orbit ; and there are two reasons why the true motions the remaining five planets differ from their mean motions ; Mercury and the other four planets revolve round the Sun in an elliptical path, which gives them in their orbits a position different from their mean positions and the other reason is that this position of planets relative to the Sun, appears still different to us (observers on the earth), since the earth constantly changes its position in the sky while revolving round the Sun.

Although our ancient astronomers did not know these reasons in thei r real perspective—two reasons in the case of five planets and one in the case of the Sun and Moon, they have unknowingly assumed the same principles to start with, while finding the places of planets ; and the true positions of planets which we obtain by following our works agree to a considerable extent, if not to the fullest extent, with those obtained by following the methods which the Westerners have established after understanding the theory. In other words, the mean position of a planet being the same, if it be found by Western methods of calculation occupying a particulars place in the sky, we too get the same or very nearly the same place by following our own works ; and the difference, if any, in the two results is due to some slight defects or approximations of the elements assumed in our calculations, and also to the fact that some other elements, in addition to the above two reasons, which have been lately discovered, were not known to our people. The following discussion will confirm the truth of the above statement that the two main reasons were indirectly known to our astronomers.

The theory underlying the method of calculating the true place of a planet from its mean place is explained in our works by means of a diagram. Here the theory is given, as it will help one to understand what the reasons are which cause a difference between the true and the mean place of a planet, and what the ideas of our astronomers were reparding this question. They draw

a circle to represent the planetary orbit, having for its centre, the centre of the earth. They draw another circle, equal to the first, such that its centre will be at a distance from the earth's centre. This circle is termed a '*Prativṛtta*' (eccentric circle) ; and the mean planet is supposed to move in that circular orbit, and the point of the planetary orbit which the mean planet would appear to occupy would be said to be its true place.



In the adjoining figure the circle whose centre is E is the planet's orbit. Similarly, the 'eccentric' circle has been drawn with C as its centre ; and point 'M.P.' in it represents the position of the mean planet and M, the corresponding position of the mean planet in its orbit. To an observer on the earth, the mean planet appears to lie in the line joining the point 'M.P.' to E. This line is called the 'Karṇa' (radius vector). This radius vector cuts the orbit circle at T, and the true planet appears to be in the orbit circle at that point. The difference between the true and the mean place, viz. the arc MT (i.e. MET))is termed '*phalasaṃskār*', (i.e. equation of centre). The maximum value of this correction is called the 'parama' or 'antya'-phalasaṃskār (max. equ. of centre). The centre C of the eccentric circle is marked away from E, the centre of the orbit circle, at a distance equal to the sine of the maximum correction. The 'phala' (i.e. correction) mentioned above, is called 'mandaphala' i.e. equation of centre. The position obtained by applying this correction, or equation of centre, to the mean place of a planet (i.e. adding the correction to or subtracting it from the mean place, according as it is positive or negative) is termed the 'manda-spaṣṭagraha' (true heliocentric place of a planet). The true places of the Sun and Moon are obtained by applying only one correction, that of the equation of centre. But, the positions so obtained in the case of other five planets are not the positions at which they would be visible to observers on the earth ; (according to modern theory they will represent the true heliocentric position, that is the position seen from the centre of the Sun). They require another correction to be applied ; it is called the '*Śīghra-phala-saṃskār*' (i.e. the annual parallax). When it is applied to the heliocentric position, one gets the position where the planet is observed from the earth. In order to find it, they assume another circle called the '*Śīghra-prati-vṛtta*' (śīghra eccentric circle) and they find the required correction by regarding the position of the heliocentric planet as that of the mean planet. The operation of obtaining the 'mandaphala' (equation of centre) is known as the 'manda-karma' and that of obtaining 'śīghra-phala' (annual parallax), as 'śīghra-karma'. The method of finding the 'śīghra phala' is expalined below :—

The orbit circle drawn in the operation of "manda karma" becomes the "śīghra-prativṛtta" in the operation of "śīghra-karma", then taking a point away from the centre of this circle, at a distance equal to the sine of the maximum value of 'śīghraphala', another orbit circle is drawn with this point as centre.

The earth itself is supposed to be at the centre of this orbit circle drawn in the operation of 'śīghra-karma'.The place where the heliocentric planet, while moving at its own rate of motion in the "śīghra-prati-vṛtta", appears to be in the "śīghra-kakṣāvṛtta" is its geocentric position. The planet appears to be at that place to an observer on the earth. Some people treat the "manda-kakṣāvṛtta" itself as the "śīghra-kakṣāvṛtta", and then they draw an equal circle called the "śīghra prativṛtta", having for its centre a point which is marked at a distance equal to the sine of 'śīghrāntya-phala' from the original centre. Then the heliocentric position of the planet from the 'mandakakṣā-vṛtta' is transferred to the "śīghra-prativṛtta", and its place as seen in the "kakṣāvṛtta" is taken to be its geocentric position. Both the methods lead to the same result.

The above diagram will show that the distance of the planet moving in the eccentric circle is not the same from the point E. The distance is greatest when the planet is at A (aphelion) and the least when it is at P (perihelion); in other words, the path of the moving planet is as it were assumed to be, elliptical. E is one focus of this ellipse.

Parameśwara, the commentator of Āryabhaṭai, has described in simple words, the method of drawing the figure for finding the equation of centre The author has not come across an equally good explanation in any other work. The author, therefore, quotes the verses here :—

त्रिज्याकृतं कुमध्यं कक्षावृत्तं भवेत् तु तच्छैघ्रयं ।।
शीघ्रदिशि तस्य केंद्रात् शीघ्रांत्यफलांतरे पुनः केंद्रं ।। २ ।।
कृत्वा विलिखेत् वृत्तं शीघ्रप्रतिमंडलाख्यमुदितमिदं ।।
इदमेव भवेन्मांदे कक्षावृत्तं पुनस्तु तत्केंद्रात् ।। ३ ।।
केंद्रं कृत्वा मंदांत्यफलांतरे वृत्तमपि च मंददिशि ।।
कुर्यात्प्रतिमंडलमिदमुदितं मांदं शनीडयभूपुत्राः ।। ४ ।।
मांदप्रतिमंडलगास्तत्कक्षायां तु यत्र लक्ष्यंते ।।
तत्र हि तेषां मंदस्फुटाः प्रदिष्टास्तथैव शैघ्रे ते।। ५ ।।
प्रतिमंडले स्थिताः स्युस्ते लक्ष्यंते पुनस्तु शैघ्राख्ये ।।
कक्षावृत्ते यस्मिन् भागे तत्र स्फुटग्रहास्ते स्युः ।। ६ ।।
मांदं कक्षावृत्तं प्रथमं बुधशुक्रयोः कुमध्यं स्यात् ।।
तत्केंद्रान्मंददिशि मंदांत्यफलांतरे तु मध्यं स्यात् ।। ९ ।।
मांदप्रतिमंडलस्य तस्मिन् यत्र स्थितो रविस्तत्र ।।
प्रतिमंडलस्य मध्यं शैघ्रस्य तस्य मानमपि च गदितं ।। १० ।।
शीघ्रस्ववृत्ततुल्यं तस्मिश्चरतः सदा ज्ञशुक्रौच ।।

"The orbit circle, at the centre of which is the earth, and whose radius is equal to 'trijyā' *is called a 'śaighra' circle (i.e. the orbit circle necessary in the geo-

*The word 'trijyā' is now-a-days used as a technical term signifying semi-diameter. But originally it stood for 'jyā' (sine) of 'tribha' (i.e. 3 signs or 90 degrees); and our astronomical works are generally found using it in that sense. When the perimeter of a circle is supposed to consist of 360°, (or 21600 minutes), the semi-diameter becomes equal to 3438'; or the sine of 90° is equal to the semi-diameter. Hence, by "trijyā" is generally meant a line whose length is 3438'.

centric calculation or 'śīghra-karma'). Another circle should be drawn with a point for its centre, which should be away from the centre (of the orbit circle) at a distance equal to maximum 'śīghra phala' and in the direction of the 'śīghra' position. This circle is termed as 'śīghra'-eccentric circle. The same becomes a 'kakṣāvṛtta' (orbit circle) in the heliocentric operation. Again, draw another circle, in the direction of the heliocentric position, having its centre at a distance of maximum equation of centre. This is termed 'manda'-eccentric circle. Saturn, Jupiter and Mars, while moving in the 'manda eccentric circle' are seen occupying certain places in the heliocentric orbit circle, and they are termed 'heliocentric'. (These are the heliocentric positions of Saturn, Jupiter, and Mars). They should similarly be treated as moving in the 'śīghra'-eccentric circle and their corresponding positions in the 'śīghra'-orbit circle would be called their 'true position' (These should be taken to be their geocentric positions). The circle having the earth for its centre, becomes the 'Manda' orbit circle for Mercury and Venus. The centres of their 'manda' eccentric circles lie at a distance, equal to their maximum equation of centre, from the centre of the orbit. The point of this circle occupied by the Sun should be taken to be the centre of the geocentric eccentric circle. The size of this circle has been mentioned as being equal to that of his 'own-geocentric-circle'. Mercury and Venus always move in that circle.

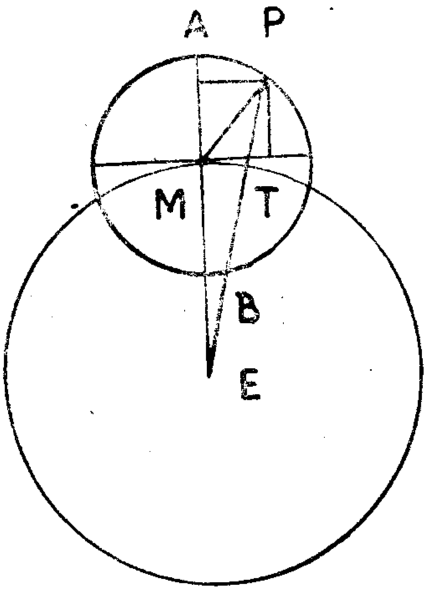
The underlying theory of the equation of centre is explained in another way by assuming a circle known as the 'nīcocca-vṛtta' (apsidal circle). BHĀSKARĀCĀRYA observes in this connexion :—

कक्षास्थमध्यग्रहचिन्हतोथ वृत्तं लिखेदंत्यफलज्यया तत् ॥
नीचोच्चसंज्ञं रचयेच्च रेखां कुमध्यतो मध्यखगोपरिस्थां ॥ २४ ॥
कुमध्यतो दूरतरे प्रदेशे रेखायुते तुंगमिह प्रकल्प्यं ॥
नीचं तथासन्नतरेऽथ तिर्यङ् नीचोच्चमध्ये रचयेच्च रेखां ॥ २५ ॥
नीचोच्चवृत्ते भगणांकितेस्मिन् मांदे दिलामं निजकेंद्रगत्या ॥
शैघ्रयेऽनुलोमं भ्रमति स्वतुंगादारम्य मध्यद्युचरो हि यस्मात् ॥ २६ ॥
अतो यथोक्तं मृदुशीघ्रकेंद्रं देयं निजोच्चाद्युचरस्तदग्रे ॥

छेद्यकाधिकार.

"Draw a circle with the mean planet in the orbit, as centre, and the sine of maximum equation of centre as the radius. It is called 'the apsidal' circle. Draw a line from the centre of the earth passing through the mean planet. It intersects the circumference of the epicycle in two points—the farthest point is called the 'ucca' (aphelion) and the nearest one the 'nīca' (perihelion). Draw a horizontal line in between the aphelion and perihelion. Mark the signs and degrees on the circumference of the 'nīcocca'- circle. The mean planet moves from the aphelion in the mānda (heliocentric) epicycle in a regular direction, and in the Śaighra (geocentric) epicycle in a reverse direction, at the same rate of motion as its anomaly (i.e. according to the motion of its mean anomaly or of the angle of commutation). Hence, the centres of the mean and true circles are to be marked in relation to the aphelion.

The planet is seen at the end of the direction line (The heliocentric place at the end of the heliocentric apse line and geocentric at the end of the geocentric apse line.)"



In the adjoining figure, the circle whose centre is E is the orbit circle. M is the mean place of the planet in the heliocentric operation and its heliocentric place in the geocentric operation, and the same point is the centre of the heliocentric or geocentric epicycle. The epicycle has been drawn with that point as the centre and the sine of the maximum equation of centre (or annual parallax) as radius. The point P in it stands for the planet, and the line joining it to the centre (E) cuts the orbit circle in the point T. It is the position of the 'true planet' (i.e. heliocentric or geocentric planet)'. Bhāskarācārya observes in regard to this theory :

ग्रहः पूर्वगत्या प्रतिमंडलेनैव भ्रमति । यदेतन्नीचोच्चवृत्तं तत् प्राज्ञैर्गणकैः फलार्थं कल्पितं ॥

गोलाध्याय, छेद्यकाधिकार.

"As a matter of fact, a planet moves in the eccentric circle itself with its original rate of motion. The epicycle has been invented by astronomers only to calculate the equation of centre."

In the above figure, of all points on the eccentric circle, A, is at the greatest distance from the centre of the earth ; it is called aphelion. B is at the nearest distance ; it is called Perihelion. The Aphelion belonging to the Manda eccentric circle, is called 'mandocca' or an 'apsis' ; and that of the śīghra eccentric circle is called the 'śīghrocca' or the apex of swift motion. The longitudes of the mandoccas of planets and their motions have been discussed in the account of Āryabhaṭa I (page 69). The mandoccas have got a very slow* motion. The Sun itself is taken to be the 'śīghrocca' for Mars and other superior planets, and our works have assumed the same motion for the śīghroccas of Mercury and Venus which these planets, according to modern theory actually have in their orbits. The above figure will show that when a planet comes to the position of aphelion or perihelion, the mean place of the planet and its true place coincide. In other words the

*Grant says (History of Physical Astronomy P. 97) that it was al-Buttānī, an Arab astronomer (880 A.D.) who first discovered that the Sun's apogee has motion. This means that it was not known to *Ptolemy* and *Hipparchus* that the Sun's apogee and the aphelia of the planets have motion. But our astronomer BRAHMAGUPTA has mentioned (628 A.D.) the motion of aphelia of planets. Moreover it is met with even in the modern S.S. Prof. whitney has simply ridiculed the fact that the motion given to the apsides of planets is very slow according to our astronomers. But the only reason of this is that his prejudiced mind could not tolerate the idea of bringing down the Westerners to an inferior position by admitting that while Ptolemy never knew that a planet's aphelion has got motion, the Hindus knew it. But the writer has already explained in his account of Āryabhaṭa I that the motion of aphelion mentioned in our old works is not as slow as Whitney considers it to be.

equation of centre is Zero. As the planet advances three signs or 90° from the aphelion, the value of the equation of centre gradually increases and then it continually decreases till it reaches the perihelion. It increases again for three signs more and finally decreases till it reaches the aphelion. In short, whatever change occurs in the mean motion of the planet is in relation to the aphelion. The Sūrya Siddhānta makes the following observation :—

अदृश्यरूपाः कालस्य मूर्तयो भगणाश्रिताः । शीघ्रमंदोच्च पाताख्या ग्रहाणां गतिहेतवः ॥ १ ॥

तद्वातरश्मिभिर्बद्धास्तैः सव्येतरपाणिभिः । प्राकपश्चादपकृष्यंते यथासन्नं स्वदिङ्मुखं ॥ २ ॥

स्पष्टाधिकार.

" The three invisible forms of time, viz. śīghrocca, mandocca and pāta which are supported by 'bhagaṇas '(revolutions) are the generators of the motions*of planets. These forms of time drag towards themselves by tossing and fro**, the planets which are tied by the reins of wind held by them."

No other siddhānta has given so much importance to the aphelia as the S. S. has done by regarding them as some animate objects. *Brahmagupta* simply remarks,

प्रतिपादनार्थमुच्चाः प्रकल्पिता*** : ग्रहगतेस्तथा पाताः ॥ २६ ॥

गोलाध्याय.

" The aphelia and nodes have been imagined as points simply to explain the phenomena of planetary motions."

Nowhere does the S. S. explicitly state that the planets move in the epicyclic orbits ; hence, it appears that the aphelia have been supposed to be some objects having forms. But when the planets are assumed to be moving in epicyclic orbits, their mean positions naturally undergo a change which simply depends upon the distance of the planet from the aphelion.

It has been mentioned above that the epicycles are supposed to be drawn at a distance from the centre of the orbit circle equal to the sine of the maximum value of the equation of centre or the annual parallax. The value of the equation of centre or of the annual parallax concerning each planet is given in our treatises, and it is the convention to give it in terms of the circumference of a circle, having the sine of maximum correction (viz. equation of centre) as semi-diameter ; in other words it is what the length of the *circumference*, expressed in degrees, would be, if a circle be drawn with the sine of maximum correction as semi-diameter ; and it is generally termed ' Paridhi ' or ' circumference '. The circumference of the circle drawn with respect to the equation of centre is called the " mandaparidhi " i.e. the dimension of the epicycle of the apsis, and that with respect to the annual parallax is called the ' śīghraparidhi ' or the dimension of the epicycle of the apex. The reason for expressing the equations in terms of epicycles seems to be the above system of drawing the epicycles of apsides. Considered independently, the circumference of the apsidal circle no doubt represents 360° ; but as the value of the equation is to be reckoned in terms of degrees of the orbit circle, the length of the perimeter of an epicycle is also expressed by the same system of degrees.

*Here, the word ' motion ' is to be taken to mean true motion.

**By " to and fro " is meant the actual position in advance of or behind the mean position of a planet. (Ranganātha has interpreted this in a somewhat different way). The position of a planet in the north or south direction changes because of the nodes.

***By ' motion ' here is meant the true motion of the planet.

The next table gives the dimensions of the epicycles related to the apsis and the apex as given by different authors ; similarly, their radii also have been calculated and given. The radii themselves represent the maximum values of their equations. While calculating the radius, the ratio of the circumference to its radius as mentioned by Āryabhaṭa I and Bhāskarācārya, viz. 62832 : 10000, has been adopted.

The arc of anomaly containing 3 signs or 90° is termed '*pada*' quadrant). The first and third are termed '*oja*' (odd) and the second and fourth '*Yugma*' (*even*). The authors of some siddhāntas hold the view that the length of the circumference related to the odd quadrants is different from that of the circumference of the even quadrants ; and that it varies in the intermediate portions proportionately. In the following table, the *paridhis* of some planets according to the Pañcasiddhāntikā have not been given, because the figures as given in that work are not known for certainity. In the case of other siddhāntas, wherever the paridhis related to the even quadrants are not mentioned, they are to be taken to be equal to those related to the odd quadrants.

MANDAPARIDHI

Dimensions of the Epicycles of Apsis and their radii or max. value of the equation of centre .

Planet	The S. S. from Paca Siddhān/tikā		Modern Sūrya Siddhānta: At the end of odd quadrant		Modern Sūrya Siddhānta: At the end of even quadrant		First Ārya siddhānta: At the end of odd quadrant	
	Circum	Radius	Circum	Radius	Circum	Radius	Circum	Radius
	°	° ' "	° '	° ' "	°	° ' "	° '	° ' "
Sun	14	2 13 41	13 40	2 10 30	14	2 13 41	13 30	2 8 55
Moon	31	4 56 2	31 40	5 2 24	32	5 5 35	31 30	5 0 48
Mars	70	11 8 27	72	11 27 33	75	11 56 12	63 0	10 1 36
Mercury	28	4 27 23	28	4 27 23	30	4 46 29	31 30	5 0 48
Jupiter	32	5 5 35	32	5 5 35	33	5 15 8	31 30	5 0 48
Venus			11	1 45 2	12	1 54 35	8 0	2 5 53
Saturn			48	7 38 22	49	7 47 55	40 30	6 26 45

Planet	First Ārya Siddhānta: At the end of even quadrant		Brahma Siddhānta: At the end of odd quadrant		Brahma Siddhānta: At the end of even quadrant		Second Ārya Siddhānta	
	Circum	Radius	Circum	Radius	Circum	Radius	Circum	Radius
	° '	° ' "	° '	' "	°	° ' "	° '	° ' "
Sun			13 40	2 10 30			13 40	2 10 30
Moon			31 36	5 1 45			31 34	5 1 26
Mars	81 0	12 53 29	70 0	11 8 27			65 30	10 25 29
Mercury	22 30	3 34 51	38 0	6 2 52			27 36	4 23 34
Jupiter	36 0	5 43 46	33 0	5 15 8			28 15	4 29 46
Venus	9 0	1 25 57	9 0	1 25 57	11	1 45 2	9 35	1 31 31
Saturn	58 30	9 18 38	30 0	4 46 29			52 42	8 23 15

Dimensions of the EPICYCLES OF APEX and their radii or max. value of the annual parallax.

Planet	The S. S. from Pañca Siddhāntikā		Modern Sūrya Siddhānta At the end of odd quadrant		Modern Sūrya Siddhānta At end of even quadrant		First Ārya Siddhānta At end of odd quadrant	
	Circum	Radius	Circum	Radius	Circum	Radius	Circum	Radius
	°	° ′ ″	°	° ′ ″	°	° ′ ″	° ′	° ′ ″
Mars	234	37 14 32	232	36 55 26	235	37 24 5	238 30	37 57 30
Mercury	142	21 0 30	132	21 0 30	133	21 10 3	139 30	22 12 7
Jupiter	72	11 27 33	72	11 27 33	70	11 8 27	72 0	11 27 33
Venus	260	41 22 49	260	41 22 49	262	41 41 55	265 30	42 15 20
Saturn	40	6 21 58	40	6 21 58	39	6 12 25	40 30	6 26 45

Planet	First Ārya Siddhānta* At the end of even quadrant		Brahma Siddhānta At the end of odd quadrant		Second Ārya Siddhānta At the end of even quadrant		Second Ārya Siddhānta At the end of odd quadrant	
	Circum ° ′	Radius ° ′ ″	Circum ° ′	Radius ° ′ ″	Circum	Radius	Circum ° ′	Radius ° ′ ″
Mars	229 30	36 31 33	243 40	38 46 50	°	° ′ ″	230 59	36 45 43
Marcnry	130 30	20 46 11	132	21 0 30			134 30	21 24 23
Jupiter	67 30	10 44 35	68	10 49 21			69 30	11 3 40
Venus	256 30	40 49 23	263	41 51 28	258	41 3 43	261 30	41 37 8
Saturn	36 0	5 43 46	35	5 34 13			40 40	6 28 20

The maximum values of the equation of centre according to Ptolemy and those according to modern European astoronomers have been given below in a table.* One can, of course, compare them with the above values given in our old treatises. But in order to facilitate such comparison, the maximum values of the equation of centre at the end of the odd quadrants as given by Āryabhaṭa I, out of our siddhāntas, have again been given below :—

MAXIMUM VALUES OF EQUATION OF CENTRE

	First Ārya Siddhānta	Ptolemy	Modern
	° ′ ″	° ′	° ′ ″
Sun	2 8 55	2 23	1 25 27
Moon	5 0 48	5 1	6 17 13
Mars	10 1 36	11 32	10 41 33
Mercury	5 0 48	2 52	23 40 43
Jupiter	5 0 48	5 16	5 31 14
Venus	2 51 53	2 23	0 47 11
Saturn	6 26 45	6 32	6 26 12

*These have been adopted from the translation of the Sūrya Siddhānta by Burgess (p. 76).

The modern values of Mercury and Venus cannot properly be compared with those given in our works, because the modern values are true only with respect to an observer on the Sun's disc while our works have given them with regard to the observer on the earth. It would not be wrong, however, if the values of other planets from both the systems are compared ; and when they are so compared, it will be seen that the values given in our works agree with the modern ones to a great extent. The orbits of the moon and the planets are elliptical according to the modern astronomical theory. The value of their equation of centre varies with the changing values of the eccentricity of their orbits ; and these values of the equation of centre as given in our works agree with the values given in modern works. The form of planetary motions as given in our works has been shown above which will show that although the writers of our works have not assumed an elliptical orbit for the movement of planets, still they have assumed that their distances from the centre of the orbit never remain the same, and that the equations vary with their position with respect to the points of apices known as aphelion and perihelion, in the orbit ; from this it would appear that ancient authors indirectly knew the main cause of the difference between the true and mean places of planets, that is the phenomenon of the movement of these planets (or of the Moon) in elliptical orbits. The annual parallax of a planet depends upon the variable distance of the planet's heliocentric position in its orbit from the earth. 'The figures showing the annual parallax as given in our works have been given in the above table (page 243) and it has been pointed out before (page 197)' that the radii vectors of planets calculated from them agree with the corresponding modern values. This fact coupled with the trend of the above discussion will show that our astronomers indirectly knew the second factor which was responsible for the difference between the true and mean position of a planet,—that the position of a planet with respect to the Sun, which is known as its heliocentric position, differs from the positions seen by an observer on the earth, because the earth also revolves round the Sun.

That none of the values given by PTOLEMY agree with the corresponding values given in our siddhāntas is one out of the many proofs* to show that Ptolemy had no concern with any of the siddhāntas.

Now some more noteworthy facts about the epicycles of apsides and apices may be mentioned. According to some siddhāntas, the dimensions of epicycles are different in the odd and even quadrants. ĀRYABHAṬA I has shown much variation in these dimensions ; the Sūrya Siddhānta does not mention so much variation. BRAHMAGUPTA has assumed different dimensions for the epicycles in the odd and even quadrants only in the case of Venus. The modern Romaśa, Soma, Śākalya Brahmasiddhānta and Vasiṣṭha siddhānta are almost similar to the modern Sūryasiddhānta ; still the measures of epicycles, as given in the Romaśa and Soma have been assumed to be the same throughout, and they agree with those of the even quadrants mentioned by the S. S. The dimension of the apsidal epicycle of mercury, given by Soma siddhānta as 34, however, does not agree (with S. S.). The Vasiṣṭha

*The Romaka siddhānta of the Pañcasiddhāntikā gives 4°57′ as the maximum equation of centre for the Moon (See 8.6. Pañc S.). This does not agree with that given by Ptolemy. This is one of the proofs to show that the Romaka Siddhānta of the Pañca Siddhāntikā was not written by Ptolemy.

siddhānta does not mention* the apsidal epicycles at all. The dimensions of the epicycles of the apices have been given, but they do not agree with those of the Sūryasiddhānta, and hence they are given below :—

Mars 234 ; Mercury 133 ; Jupiter 71 ; Venus 261 ; Satur 39.

Theses are the same for both the quadrants, and though they do not agree with the Sūrya Sidhānta, they are easily seen to be approximately mean measures of the two kinds of quadrants. The copy of the Śakalya Brahma siddhānta in the author's possession does not mention any epicycles at all ; but there undoubtedly appears** to be in this copy, a break at the place where they are expected to have been mentioned. They must have been given in the original work. *Lalla* being the follower of Āryabhata I, the measures of epicycles given by both of them are indentical. Similarly BHĀSKARĀCĀRYA was the follower of Brahmagupta and both have therefore, given the same measures. But Bhāskarācārya has mentioned 50° as the measure of the apsidal epicycle of Saturn and 40° as that of its epicycles of apex. The Sundursiddhānta of JNĀNARĀJA has given measures of epicycles similar to those of the modern Surya Siddhānta. According to Muniswara,, the author of Siddhānta Sārvabhauma, it is illogical to asume different measures for the epicycles in the odd and even quandrants. He has given the mean values of the measures of the epicycles in the odd and even quadrants given in the modern Surya Siddhānta. Different Karaṇa works show some variations the measures of epicycles ; but it appears to be due to the fact that sufficient attention was not paid to their accuracy. There is nothing specially worth mentioning about them.

The modern values of the equations of centre are given above ; but they are not always the same. They very with the lapse of time. The following table *** gives an idea of the long-period variation affecting the value of the Sun's equation of centre.

Years before Śaka era	Maximum value of eqn. of centre °	′	Years after Śaka era	Maximum value of eqn of centre °	′
10000	2	31	0	2	1
9000	2	28	1000	1	58
8000	2	25	2000	1	55
7000	2	22	3000	1	52
6000	2	19	4000	1	49
5000	2	16	5000	1	46
4000	2	13	6000	1	43
3000	2	10	7000	1	40
2000	2	7	8000	1	37
1000	2	4	9000	1	34
0	2	1	10000	1	31

* It is found neither in the edition printed at Varanasi nor in the version in the Deccan College collection.

** The second chapter begins abruptly after an incomplete line of the verse : "Maurvya Catuṣke", which is given after 111 verses of the first chapter. The second chapter opens with an unexpected question. It seems that the epicycles may have been mentioned in between. It is surprising that the break was found precisely at the same place in the copies seen at Gwalior, Asta, and later on in the Anandāśrama copy (No. 4341).

*** This table has been taken from the Planetary Tables of Keropant.

The table shows that the correction due to the equation of centre, in the case of the Sun, is gradually diminishing. This correction, according to our works, ranges from 2° 13′ 41″ to 2° 8′ 55″. It may be noticed that the more ancient treatises have given a greater value and the modern works a smaller one, as can be seen from the above table (page 242). It is easily seen that the value was determined after actual observations were taken at different times. Our astronomers have determined the correction figures for the Sun and Moon from the observations of their eclipses, that is from their positions at the moments of lunations. The modern European method of finding the true place of the Moon from that of its mean place, requires the application of five main corrections. It has been shown further that our people had determined a value as the maximum equation of centre for the moon, which is equal to the sum of the four (out of five) corrections applicable at the moment of lunation. The maximum value of the fifth correction of the equation of centre is 11 minutes. (Planetary Tables, by Keropant, p. 105). As its argument is Sun's anomaly, it was taken to be applicable to the Sun with minus or plus sign, where it was actually to be applied to the Moon with plus or minus sign. This has not affected the result of the calculation of the eclipse. If 11′ be subtracted from 2° 14′, which is the value of the sun's maximum equation of centre as given in our ancient works, our works can, in fact, be said to have given 2° 3′ as the correction for the Sun, and that was actually the value in the year 500 B.S. Hence, our people appear to have found out the cerrection for the Sun at that early period or at least two or three centuries before Śaka era. The equation of centre for the Sun, according to Ptolemy, is 2° 23′, which means that he had nothing to do with our works. Although PTOLEMY has given 2° 23′ as the Sun's correction, it was actually 2° in his time (about Śaka 70). Obviously it was not found by *Ptolemy* himself, but probably adopted from some previous writer. The fact that no one except *Hipparchus* possessed, before him, the knowledge of calculating the true place of the Sun and the fact that the length of the year according to Ptolemy and Hipparchus was the same* measure ($365^{d}\ 14^{g}-48^{p}$) lead one to infer that Ptolemy had adopted the value of the Sun's equation of centre from Hipparchus. This inference is further confirmed by the fact that the Romaka siddhānta which was compiled on the basis of the work on Hipparchus has adopted 2° 23′ 23″ as the maximum equation of centre for the Sun. No one ever says that the Hindus borrowed astronomy from some work compiled after Ptolemy. No astronomer of equal capability flourished within 3 or 4 centuries after Ptolemy. None of our Siddhāntas contain the same equation of centre for the Sun as was given in the original Romaka Siddhānta. From all these facts, any impartial thinker will have to admit that it is proved beyond all doubt that our astronomers did not borrow the figures for the equation of centre for the Sun from any European work, but that they themselves determined it before the Śaka era.

The modern maximum values of the equation of centre that have been given above (page 242) show that the equation of centre for the moon is 6° 17′. But there are certain factors, other than the equation of centre, which cause a difference between the Moon's mean and true places ; and these sometimes cause a variation of 8° to 8½° between the mean and true places of the Moon. For finding this, about 40 corrections are required to be applied. Of these, the correction khown as the equation of centre, mentioned above, is a very large figure and the other four corrections are also appreciably large. Of

*Grant's *History of Physical Astronomy*, Chap. XVIII.

these, the one known as 'variation' (pākṣika or taithik) has "moon *minus* true sun" as its argument. This argument will, of course, become 6 signs and zero at the moment of the full moon and the new moon respectively, and this correction too becomes zero* at these moments. Similarly, for calculating the second of the four corrections, known as "evection" (cyuti), the argument is [$2\times$(corrected moon—true sun) —moon's anomaly].

The first term in this formula becomes zero at the moment of the full moon and new moon ; and the argument is reduced to (zero *minus* moon's anomaly) at that moment. When the value of the argument is three or nine signs, the correction attains its maximum value viz. $1^\circ\ 20.2'$. Hence, if the moon's anomaly at the time of the full or new moon is 3 or 9 signs, the argument for calculating the correction due to evection becomes "zero minus three signs" i.e. 9 signs or 'zero *minus* nine signs' i.e. 3 signs and the corresponding values of the correction due to evection become respectively $+1^\circ\ 20'$ and $-1^\circ\ 20'$**, and at that time, if the moon's anomaly is 3 signs, the equ. of centre becomes $-6^\circ\ 17'$ and if the moon's anomaly is 9 signs, the equ. of centre becomes $+6^\circ\ 17'$***.

Hence at the moments of full or new moon, the maximum value of the correction, as given by the equation of centre and the evection together, would not exceed $\pm 1^\circ\ 20' \mp 6^\circ\ 17' = \mp 4^\circ\ 57'$.

One correction of $11'$ out of the four has been applied to the Sun as already explained. The fourth correction is about 7 minutes.**** Applying it to the above figure of $4^\circ\ 57'$, we get $5^\circ\ 4'$. The remaining 35 out of 40 corrections are very small. In short, the maximum value of the moon's equation of centre as given by our siddhāntas, which lies between $4^\circ\ 56'$ and $5^\circ\ 6'$, has proved to be very accurate†. The best means of testing the accuracy of the values of the equations of centre in the case of the sun and moon are the eclipses ; and it has already been observed before (pages 60, 130 etc.), that our astronomers have determined the corrections for the Sun and Moon with the aid of the eclipses.

Sudhākara states that *Munjāl* has mentioned a correction similar to that of evection and another like variation, and that *Nityānanda* has mentioned those for variation and for the nodes.

No Western astronomer before *Ptolemy* knew how to find the true places of the five planets ; even *Hipparchus* did not know it††. And the maximum values of the equation as given by Ptolemy do not agree with those given in our works. This shows that our astronomers have themselves found out the method of calculating the true places of the five planets. The calculation of the true places of the Sun, Moon and the five planets is the most important part of mathematical astronomy ; in fact it is the quintessence of astronomy, and this we have decidedly not borrowed from Westerners.

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* Keropant's Planetary Tables, p. 110.

** Keropant's Planetary Tables, p. 106.

*** Keropant's Planetary Tables, p. 109.

**** Keropant's Planatary Tables, pp. 105 & 111.

† The above explanation about the equation of centre relating to the Sun and Moon was suggested by Venkateś Bāpūji Ketkar.

††Grant's *History of Physical Astronomy*, Chap. XVIII.

The equation of centre is found by the formula

$$\frac{\textit{epicycle} \times \textit{sine of anomaly of planet}}{\text{semi-diameter}}$$

The 'Kendra' (anomaly) is the difference between the place of the planet and that of the aphelion. The Sun and Moon require only one correction, that of the equation of centre. Others require two corrections, the equation of centre and the annual parallax. The calculation requires the use of the planet's distance from the earth ; and in order to find the equation of centre accurately, one has to use the method of successive approximation.

Sines and Radius

The siddhānta works give sines of divisions of circle, each of which is equal to $3\frac{3}{4}°$. The Karaṇa works use divisions consisting of 10° to 15° each since they are not very particular about accuracy. Most of the siddhāntas have assumed 3438 as the value of 'trijyā' (radius) while calculating values of sines. Brahmagupta has assumed it to be 3270. Kamalākara, the author of Siddhāntatattva-viveka has mentioned sines of each degree of the quadrant assuming 60 as the value of the 'trijyā'. The Karaṇa works generally take 120 as the value of the trijyā. According to Sudhākara, Munjāl has adopted 8° 8′ as the 'trijyā' and Gangādhara, author of Cāndramāna (page 195) has adopted 191 as the measure. The work Yantrarāj has adopted 3600 as the 'trijyā' and given the sine of each degree of the quadrant. Keropant Nānā remarks* that the value of 'trijyā', 3438, which this Hindu astronomers adopt is an awkward figure entailing unnecessary multiplication and division. This is to a certain extent, true. But our astronomers have at places made use of artifices to avoid lengthy multiplications and divisions ; and the reason for adopting that figure for the radius is a rational one, inasmuch as the circumference of the circle is equal to 21600 minutes and the radius computed from it comes to 3438. The most accurate ratio of the diameter to the circumference is 1 : 3·1415927. On the basis of this ratio, if the circumference be 21600, the semidiameter comes to $3437\frac{3}{4}$. Our astronomers have adopted 3438 as the value after leaving out the fraction. This will show that the value of 'trijyā' adopted by our astronomers is very accurate†. Our ancient authors have assumed different figures as the ratio of the diameter to the circumference. They are given below :—

Sūrya Siddhānta, Brahmagupta, Āryabhaṭa II	.. 1 : √10 or 1 : 3.1623
Āryabhṭa I	.. 20000 : 62832 or 1 :3.1416
Āryabhaṭa II & Bhāskarācārya**	.. 7 : 22 or 1 : 3.1428
Bhāskarācārya	.. 1250 : 3927 or 1 : 3.1416
3438 as the radius gives	.. 1 : 3.14136
Precise Modern European value	.. 1 : 3.1415927

Evidently our people had a very accurate knowledge of the ratio of the diameter to the circumference. If they have, at places, adopted an approximate value, it is only with a view to simplifying calculations in practical work.

* See Planetary Tables, page 314.

† The European mathematicians assume the value of a 'tryijā' as equal to the 10th or some other power of 10. They have ready made tables for the purpose, which give sines and other ratios of each minute of arc ; and as the triiyā is a very large number greater accuracy is ensured.

** Āryabhaṭa II and Bhāskarācārya each has mentioned this ratio in two ways.

Brahmagupta has given in the following verse the reasons for adopting 3270 as the value of the semi-diameter :—

भगणकलाव्यासार्धं भवति कलाभिर्यतो न सकलाभिः
ज्यार्धानि न स्फुटानि ततः कृतं व्यासदलमन्यत् ।। १६ ।।

गोलाध्याय.

Accurate calculation shows that the radius, corresponding to 21600 as the circumference, is not the whole number 3438, and it is true that because of this the " first sines " are not very accurate. But the author does not think that the value of the semi-diameter viz. 3270 which Brahmagupta has adopted on the basis of the ratio 1 : √10 of the diameter to the circumference or by some other method can be justified.

The question of calculating sines and their origin has been dealt with as great length by Bhāskarācārya. Even the author of Siddhāntatattvaviveka has given much thought to it. It is not necessary to deal with it here in detail. Playfair (1782 A.D.), an European scholar, observes about the origin of sines in our treatises, " The method devised by Hindu astronomers to find the sines implies the following proposition* :—'The ratio of the sum of the sines of the first and the last of three arcs in arithmetical progression to twice the sine of the middle one is equal to the ratio of the cosine of the difference of the arcs to the radius'—This proposition was apparently not known to European mathematicians till the beginning of the 17th century". It is really creditable to our people. Similarly the Greeks only knew what a chord is, but they did not know to make use of the first sines (jyārdha). Even the Arabs didn't know of it till the 9th century A.D. It has been pointed out in the account of Āryabhaṭa I that it was known to our astronomers from Śaka 421. Our people, however, did not have an idea of the tangent and the secant. Their purpose was, however, served by sines alone.

OTHER MATTERS

The question of finding when planets become direct or retrograde and when they rise and set, these and other like matters of secondary importance are dealt with in the chapter on true motions. It is not necessary to deal with them at length here.

DECLINATION

Our works assume 24° as the maximum declination of the Sun. The obliquity of the ecliptic had reached that value 2400 years before the aka era. It is 23° 27′ 10″ in the beginning of śaka 1818. This means that the maximum declination at the present time, as calculated from our works, is wrong by 32′ 50″. The obliquity about Śaka 400 was about 23° 39′. Ptolemy's work (SYNTAXIS, Part I) mentions it as a value lying between 23° 50′ and 23° 52′ 30″, and it seems to be Prof. Whitney's opinion** that he borrowed this value from the works of Hipparchus. As this value of obliquity does not agree with the value given in our works, it is obvious that our people did not borrow their figure from the works of Hipparchus and Ptolemy. They must, of course, have found it independently and some time before the Śaka era. The work entitled, Yantrarāj, assumes 23° 35′ to be the obliquity. (In fact, this was correct about Śaka 900). But no later writers accepted it nor did they attempt to find it for themselves.

* Asiatic Researches, Vol. IV.
** Transaltion of the *Sūryasiddhānta* by Burgess, p. 57.

CHAPTER II

PAÑCĀṄGA

(Almanac)

The calculation of the five elements or parts (*aṅgas*) of the Almanac (Pañcāṅga) is usually given in the Spaṣṭādhikāra (the chapter on true Places); and hence, the question of the almanac is being taken up in this very chapter. Such matters as the Śaka era, the beginning of the year, the samvatsara (year), the "pūrṇimānta" and "amānta" systems etc. are but integral parts of the almanac; after considering these, therefore, the consideration of the five elements of the almanac, the defferent kinds of almanac etc., will be taken up.

Astronomical calculations require some moment of time to start with in order to predict future planetary positions. In accordance with this convention, the siddhānta works assume the commencing moment of Mahāyuga or that of some other Yuga and especially that of the Kaliyuga as the starting moment for calculation; and the Karana works assume some particular year of the Śaka era as the commencing year. A Karana works two however, can be found to have adopted Vikram Samvat along with the Śaka era. Thus the Karaṇa work *Rāmavinod* has adopted Akbar year along with the Śaka year, and the *Phatteśāha Prakāśa* has adopted the Phatteśāha year coupled with the Śaka year. The *Vārṣiktantra* (page 167), which is really a Karaṇa work has adopted the commencement of the Kaliyuga for the epoch for calculation, and the author has accordingly classed the work as 'tantra'. Even than it has brought in some association with the Śaka era.

A study of different eras

Our almanacs, in their opening pages which are usually devoted to the study of the "samvatsaraphala" (forecast of the year), refer to six founders of eras for the Kaliyuga, like *Yudhiṣthira*, *Vikrama*, *Sālivāhana* and others. Of these, Yudhiṣthira and the other to lived in the past and the remaining three are yet to be born. The word Śaka, in fact, denotes a certain tribe of people. Bhaṭotpala and others have stated that the era was introduced under the name of Śaka, since the time when Vikrama defeated the Śaka kings. But this does not appear to be reasonable. The *Śaka* kings themselves may have started the reckoning of the era in their own name. The word Śaka originally denoted a particular tribe, but in compound words like Yudhiṣthira Śaka, Vikrama Śaka etc., it signifies time, generally known as 'Era' in English and as 'San' in Arabic. The word 'Kāla' (time) is found to have been used in the sense of era in ancient copper plates. For instance, Śakanṛpa Kāla, Vikrama Kāla, Gupta Kāla (meaning—the era started in the name of Gupta Kings) are some examples of the usage of the word Hence, the word Kāla has been used in the sense of era in the discussion which follows.

Expired year and current year

A number of eras like Vikrama era and Śaka era had been and still continue to be, in use in our country. A brief description of them may be given here.

Before doing so, however, let some idea be gived about two types of the year : the expired and the current. In the account of Brahmagupta (page 90) the date of compilation of the *Uttara Purana* has been stated to be Śaka 820. But the positions of planets, purporting to be true for the year 820, are found to agree with those for what would be Śaka 819, according to the present mode of reckoning. Hence, one begins to doubt whether the real date of compilation of the Purāṇa was Śaka 819 or 820. The Śaka year which is mentioned as "Śaka 1818" by the almanac-makers of this province and of most of the Provinces in our country is found to have been counted as Śaka 1819 in the Tamil and Telegu almanacs and in some of the Kannad ones printed in Mysore. The reason for this difference appears to be this : The positions of planets given in Siddhānta works are true for the initial moment of the first year of the Kaliyuga. Supposing the positions of planets in the beginning of the 11th year of the Kaliyuga are required, they must be found by adding to the original positions the motion of planets for 10 years, since 10 years would have been elapsed from the beginning of the Kaliyuga to the desired moment. In such calculations the number 10 has to be taken instead of 11. The two dates of compilation of the above Purāṇa, viz. 819 and 820 may possibly be accounted for in some such way. In other words 820 is the current year and 819 the expired year in this case. Similar examples are found in copper plate and other inscriptions. It has been pointed out above that the Śaka year which is numbered 1818 in these parts is counted as 1819 in some almanacs of the Madras Presidency : But there is doubt if the people of that region are really aware of the difference between the expired and current years and if it is taken into account at all for practical purposes. Now-a-days the Tamil almanacs compiled by *Anna Ayyangar* of *Tanjore* District, are in general use in Tamil country of the *Madras* Presidency. The author has procured a number of such almanace for the last several years. Among these, the almanac for the last Sarvajit samvatsara mentions the corresponding Śaka year to be 1809, while the almanac for the very next year, known as Sarvadhārī, compiled by the same author gives 1811 as the Śaka year. These year were counted as 1809 and 1810 in other provinces. It seems that the almanac-makers themselves do not clearly understand the distinction between the expired year and current year ; how can we then expect others to understand it ? On enquiries made of the well-known *Natesh Sastri* of *Madras* and the eminent scholars *Sundareshwar* Shrotni and *Vyankateshwar* Dikshit, from Tiruvadi in *Tanjhore* District, the author has learnt that the year described as "current" above is not at all in vogue in those parts at present. Hence, there is reason to believe that the distinction between the expired and current years must be merely imaginary and that it arose when two different numbers might have been applied by someone to the same year by mistake. If any such distinction exists at all it can possibly be true only with respect to the Kali era and Śaka era which are in use in works on astronomy ; and of these two, the distinction can be applied with greater clarity to Kali era. The Vikrama and other eras are not in use in astronomical works and no such distinction can be found in their case. However, examples are found in which two different numbers are applied to the same year of the Vikrama era ; but it must be the result of an error. In short, on full consideration the author is led to believe that, as a matter of fact, there is no such distinction as expired and current year. All years are only current years. For example, the present year (when the author is writing this chapter) named Durmukh (Śaka 1818) is actually 'current'. Later on, in the study of different eras, figures denoting corresponding years have been given

—and compared, and in so doing the system used for reckoning the year number is the same as the one prevalent in most parts of India. In some places the terms 'current' and 'expired' have been used; but they have been used for differentiation in the case of only those years, to which two different numbers are likely to be applied. Let us now consider the different eras.

The KALI Era

The Kali era is used for calculating time in astronomical works and in alamancs. Its years are both **Caitrādi* (luni-solar, beginning from Caitra) and Meṣādi (Solar, beginning from Aries Ingress). The almanacs mention sometimes the current year of this era, sometimes the expired year and sometimes both. It is not met with very often in epigraphical records. This era is not at all used for civil purposes at present. Some almanacs in the Madras Presidency, however, state the year only according to Kali era. The year (expired) according to Kali era is obtained by adding 3179 to the Śaka year.

The SAPTARṢI Era

This era is at present in use in *Kashmir* and the neighbourhood. It seems that it was in use in Kashmir, *Multan* and some other parts at the time of *Albiruṇī* (Śaka 952). The *Rāja-Taraṅgiṇī* has described all historical events only in terms of the years of this era. The era is sometimes known as the "Laukika Kāla" (civil time) or the Śāstra Kāla, (scientific time). This system of measuring time originated in the supposition that the Saptarṣi stars (the Great Bear) have motion, that they take 100 years to pass through one nakṣatra and that they revolve through the zodiac once in 2700 years; thus a cycle of 2700 years has been adopted for reckoning time. But in practice the century figure is usually left out. When 100 years are completed, the counting begins afresh as the first year, second, and so on. According to the astronomers in Kashmir, the Saptarṣi era began from the first lunar day of the bright half of Caitra, in the current Kali year 27. In order therefore, to find the corresponding year of the Śaka era, one has simply to add 46 to the Saptarṣi year, neglecting the centuries; and similarly if 24-25 added one gets the year according to Christian era. The "Saptarṣi" years are Caitrādi. *Dr.* ***Kielhorn* finds that the years in this system are 'current' and the months 'pūrṇimānta' (full moon ending***).

The VIKRAMA Era

This era is at present in use in Gujerat and the whole of northern India except Bengal. The people of these parts have migrated to other provinces but they have carried the use of the era with them. The year of this era is Caitrādi in Northern India. (In other words, the Samvat begins from Caitra). The months are *pūrṇimānta*. But in *Gujerat* the year is Kārtikādi and the months are amānta. In some parts of *Kathiawāḍ* and *Gujerat* the Samvat year is Āṣāḍhādi and the months are amānta. *Prof.******Kielhorn* has examined

**Caitrādi* means "beginning from Caitra"; *Kārtikādi*, "beginning from Kārtika"; *Meṣādi*, "beginning from Sun's entry into sidereal Aries". (R.V.V.)

** Indian Antiquary, XX, page 149 ff XX.

*** The amānta and pūrṇimānta systems are discussed later on.

**** Indian Antiquary, XX, p. 398 ff.

150 ancient inscriptions bearing dates of the Vikrama Samvat (year) 898 to 1877 and has arrived at the following conclusions :—(1) In the case of this era, the expired year is ordinarily in use. Sometimes * the current year is used. (2) In the beginning, the Vikrama era was Kārtikādi, but it seems that owing to the increasing influence of the Śaka era, it gradually changed over to Caitrādi reckoning on the north side of the Narmadā. In the fourteenth century of this era, both kinds of years, the Caitrādi and the Kārtikādi, could be met with in the same tracts of country, the Kārtikādi type being more prominent. (3) The months in the 'Kārtikādi' kind used to be both pūrṇimānta and amānta. The Caitrādi year generally consisted of pūrṇimānta months, but there does not appear to be any hard and fast rule followed in this respect.

The era used to be called the *Mālava era* from 450 A.D. to 850 A.D. The earliest inscription containing the word *Vikrama* belongs to *Vikrama Samvat* 898 ; but even in that inscription it is not clear if the word Vikrama has been used to indicate the name of King Vikrama. The earliest reference of this type in clear terms is found in a poem written in Vikrama Samvat 1050. The Vikrama era is at present known as Vikrama Samvat or simply as Samvat. The word 'Samvat' is really the corrupt form (abbreviation) of the word, 'Samvatsara' and it has been used indiscriminately in that sense in a number of words like Śaka samvat, Siṃha samvat, Valabhisamvat etc. Some almanacs of Madras and the neighbouring regions give the current year of the Vikrama era along with that of the Śaka era. For example, the year which is numbered as Śaka 1818 in these parts is mentioned in those almanacs as Śaka year 1819, and Vikrama Samvat 1954. The Kārtikādi Vikrama year is obtained by adding 134/135 to the Śaka year, and the Caitrādi Vikrama year by adding 135.

The CHRISTIAN Era

This era has come into vogue only since the establishment of the British rule in our country. The year of this era is Sāyana Saur (tropical solar). It begins from the 1st of January. At present, the month of January begins in the 'amānta Mārgaśīrṣa or Pauṣa**. But it used to begin in amānta Pauṣa or Māgha before 1752 A.D. when the 'New Style' was adopted in England. The year of the Christian era is obtained by adding 78 or 79 to the Śaka year.

THE ŚAKA ERA

The astronomical Karaṇa works use this era almost exclusively. It has lasted so long only because it has been espoused by astronomers ; otherwise it would have fallen into disuse long ago like the Gupta era, the reignal era of Śivājī and several such other eras. The era is, at present, exclusively used for civil purposes in the whole of South India, except in *Tinnevelli* and part of *Malabar*. It is used in addition to local eras in other parts of India. The year of this era is both lunar and solar. The solar year is used in the Tamil country and Bengal, and the lunar year is followed in other provinces. The lunar year is 'Caitrādi' and the solar year is 'Meṣādi'. The (lunar) months of this year are pūrṇimānta in the North and "amānta" in South India.

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* But refer to the statement above regarding expired and current years.

** The original gives here " Pausha or Magh ", which is probably a printer's error. (R.V.V.)

THE CEDI OR KALCURI ERA

This era is not in use at present. Prof. *Kielhorn* examining the dates contained in ten copper plates and other inscriptions of this era from 793 to 934, has come to the conclusion that the first lunar day of the bright half of Āśvina, in the 'Caitrādi' Vikrama Samvat 305, (*i.e.* Śaka year 170 or 248-49 A. D.) is the first day of the first year of the Cedi era. Consequently years of this era are Āśvinādi and they are used as current years and months are 'pūrṇimānta. The Śaka year is obtained by adding 169-70 to the Cedi year, and the year of the Christian era , by adding 247-48 to it. The era was used by the *Kalcuri* kings of Western and Central India, and it appears to have been in use in that part of India in still earlier times. The author thinks that the first lunar day of the dark half of the pūrṇimānta Āśvina or the same day of the amānta Bhādrapada was the first day of the Cedi year.

THE GUPTA ERA

This era is also not in use at present. *Dr. Fleet* has treated it at great length.* After examining the inscriptions from the year 163 to 386 of the Gupta era, he was led to conclude that its years are 'current', and Caitrādi, the months are pūrṇimānta and the epoch is Caitra Śukla Pratipadā of Śaka 242. When 241 is added to the Gupta year, one gets the Śaka year, and when 319-20 is added, the corresponding year of the Christian era is obtained. The era was in use in Central India and Nepal, and was used by the Gupta kings.

THE VALABHI ERA

This is merely a continuation of the Gupta era with its name changed into Valabhi. It was introduced in *Kathiawaḍ* in its fourth century, and at that time its year used to begin from Caitra. But the day of beginning receded five months when it was shifted to the preceding Kārtika Śukla Pratipada.

Its year is 'current' and Kārtikādi. Its months are both 'pūrṇimānta' aid 'amānta'. If 240-41 is added to the Valabhi year, the Śaka year is obtained and if 318-19 is added one gets the year of the Christian era. The inscriptions so far discovered which are dated in the Gupta and Valabhi era range from the year 82 to 945 of that era.

HIJRĪ ERA

This era originally belonged to Arabia. It was imported into this country under Muslim rule. The word 'Hijrā,' means flight. MUHAMNAD the proph et fled from Mecca to Madina on Thursday night (Friday night according to Muslim reckoning), the first lunar day of the bright half of Śrāvaṇa of Śaka 544, *i.e.* on 15th July 622 A. D. Hence, this era is called the Hijrī era ; and the date of flight is taken to be the date of its beginning. The months of this era, Muharram etc., are lunar ; and as it is not customary to insert an intercalary month, the year is strictly lunar, consisting of 354 or 355 days ; and hence, the advance of the year number of this era, compared with the advance of the year number of any solar era, shows an increase of one, every 32 or 33 solar years.

* *Corpus Inscrip. Ind.* Vol. III, *Gupta Inscriptions. Indian Antiquary,* Vol. XX p. 376 ff.

The month begins on the first or second lunar day of the bright half, from the moment of the heliacal rising of the moon. Instead of numbering the days of the month as the first day, the second day etc. they call them as the first moon, the second moon, and so on. Such 'moons' (*i.e.*, days or dates) number 29 or 30 during the month. The day of the week and the date begin from sunset. Hence, what is a Thursday night to us is a Friday night to the Muslims. During day time the name of the day is the same for both.

THE BENGALI SAN

This is in use in Bengal. Its year is solar and it begins from 'Meṣa Saṃkrānti' i. e. the Sun's entry into Aries. The names of the months are lunar and they are Caitra, Vaiśākha etc. The month which begins from 'Meṣa Saṃkrānti is called Vaiśākha (The same month is called Caitra in Tamil country). The year 1300 of the Bengali san is equivalent to Śaka year 1815 and A. D. 1893-94. The Śaka year is obtained by adding 515 to the Bengali year : and the A. D. year by adding 593-94.

THE VILAYATI SAN

This era is in use in parts of Bengal and chiefly in Orissa. Its year is solar : but the months have lunar names and the year begins on the Kanyā (Virgo) Saṃkrānti day. In Bengal, the month begins from the second or third day after the saṃkrānti ; but the month of the Vilayati San begins on the saṃkrānti day itself*. The Śaka year is obtained by adding 514-15 to the Vilayati year and the A. D. year by adding 592-93.

THE AMLI ERA

This era is thus described in Giriśa Candra's "Chronological Tables" : "The Amli commences from the birth of *Indradyumna*, Rājā of *Orissa*, on Bhādrapada Śukla 12th, and each month commences from the moment when the Sun enters a new sign." It appears that its months are solar, but the year is lunisolar. It is likely that the months also had been lunar. The Kanyā Saṃkrānti may occur on any day before or after the 12th lunar day in Bhādrapada Śukla. The Vilayati and Amli Sans are allied as they have the same epoch of reckoning and the same numerical designation.

THE FASALĪ SAN

This is the harvest year introduced by *Akbar*. Originally bearing the same number as the year of the Hijrī era. But the Hijrī year is stricIty lunar (consisting of 354 days) while the Fasalī year is solar. Because of this difference, the year numbers began to differ as time went on. The Fasalī San was introduced in Northern India in the Hijrī year 963 *i.e.* 1556 A. D. when *Akbar* ascended the throne; and emperor Shahjahan introduced it in South India in the Hijrī year 1046 *i.e.* in 1636 A. D. In the beginning, the year was assigned the same number as the year of the Hijrī era, which was 1046.But at that time, the Fasalī year in Northern India was 1044. Hence, the Fasalī year number in the Deccan exceeded the year number int he north by 2. (It so happened because the

* Warren writes in 1825 A. D. that "the Vilayati year is reckoned from the first of the Kṛiṣṇa pakṣa in Caitra" (Kala Saṇkalita, Tables p. IX). It may have been the practice at some places.

Hijrī year is purely lunar). As the year beginnings were different in the two parts, an additional difference of some months occurred. As this year was purely official and had no connexion with religious affairs, the year beginnings appear to have been irregular. In *Madras*, this year originally used to commence on the first day of the solar month Ādi (*i.e.* Karka or Cancer). In the year 1800 A. D. the British Government fixed the 13th of July as the permanent initial date and later on in 1855, altered this to the 1st of July. In parts of *Bombay* the Fasalī begins when the Sun enters the Mṛga Nakṣatra (at present on the 5th, 6th, or 7th of June). It is thus a solar year ; but its months, Muharram etc. are lunar. In northern India, the Fasalī year generally begins from the 1st lunar day of the dark half of the 'pūrṇimānta' Āśvina. In other words, the Fasalī year is in that part luni-solar. In Bengal, the Fasalī year 1300 commenced in September 1892 A. D. and in Southern India the Fasalī year 1300 commenced in June or July of 1890 A. D. In Southern India the Śaka year is obtained by adding 512-13 to the Fasalī year and the A. D. year, by adding 590-91. In Bengal, however, the Śaka year is obtained by adding 514-15 to the Fasalī year and the A. D. year by adding 592-93. The year number of the Bengal Fasalī, Vilayati and Amli Sans is the same for all days of the year except 18 days at the most. The Bengali San lags behind all these Sans only by 6 or 7 months. In fact, the Fasalī San is the origin of the Bengali, Vilayati, Amli and Bengali Fasalī Sans. It is clear that the variations in the year beginnings began to arise later.

THE SŪR-SAN OR ŚĀHŪR-SAN

This is sometimes known also as the Arabi-San. The Sūr-san commenced in the Hijrī year 745 *i.e.*, in 1344 A. D., and in the beginning, it was assigned the same number as the Hijrī year viz. 745. The Fasali San came into use in the Deccan 292 years after the Sūr-san i.e. in the Hijrī year 1046, and that year according to the Sūr-san was 1037. Hence, a difference of 9 years occured between the Sūrsan and the Fasalī San in the Deccan. The Sūr-san was extensively used during the Marāṭhā Supremacy. It is nine years behind the Fasalī San in use in the Bombay Presidency , but the two are similar in all other respects. The year of this San begins when the Sun enters the Mṛga Nakṣatra. In other words, its year is solar ; but its months, Muharrum etc. are lunar. When 521-22 is added to the Sūr-san, one gets the Śaka year, and when 599-600 is added, the A. D. year is obtained.

The Bengali, Vilayati and Amli are special varieties of the Fasalī San prevalent in the north, and the northern Fasalī, the southern Fasalī and the Sūr-san are special varieties of the Hijrī era.

THE HARṢA KĀLA

This era was founded by HARSAVARDHANA, king of *Kanauj*. It was in use in *Mathurā* and *Kanauj* at the time of *Alberuni*. It is not now in use. More than ten Copper (*plate and other*) inscriptions dated the first and second centuries of this era have been discovered in Nepal. In all those inscriptions the years are qualified only by the word 'samvat'. The Śaka year is obtained by adding 528 to the year of the Harṣa era and the A. D. year by adding 606-607.

THE MAGI SAN.

This era is current in the District of Chittagong. It is 45 years behind the Bengalī year ; the two are very similar in other respects*.

THE KOLLAM ERA OR PARAŚURĀṂA ERA

The year of this era is known as the *Kollam Āndu*. Kollam means Western, and *Āndu* means a year. The era is in use in *Malabar* from *Mangalore* to *Kumari* (Cape Comorin), and in the Tinnevelli district. Its year is Sidereal solar. The year begins from the Solar month of Kanni (*i.e.* Kanyā or Virgo) in North Malabar and from the month of Ciṅgam (or Siṃha, Leo) in South -Malabar and *Tinnevelli*. The names of months prevalent in Malabar are the corrupt forms of the rāśis. The years run in cyles of 1000 and the present cycle, is said to be the fourth. But in actual modern use the number has been allowed to run one over 1000, the year number corresponding to Śaka year 1818 being Kollam 1072. The Śaka year 747 was the first year of the Kollam era. The Kollam era does not appear to have been in use before this date. By adding 746-47 to the Kollam year one gets the Śaka year and by adding 824-25, the A. D. year is obtained.

The NEVĀR ERA

This era was in use in Nepal up to Śaka 1690. Its years are Kārtikādi and the month samānta. The era is called the *NEPALI ERA* (in Sanskrit manus-cripts) and in copper plate and other inscriptions. The corresponding Śaka year is obtained by adding 800/801 to the Nevār year, the corresponding A. D. year by adding 878/879 and the Kārtikādi Vikrama Samvat by adding 935 to it.

The CĀLUKYA ERA

The Cālukya king *VIKRAMĀDITOA* Tribhuvana Malla**instituted this era about the Śaka year 998. It seems to have ceased after *Vijala Kalacuri* defeated the Eastern Cālukyas in Śaka 1084. The system of months and pakṣas in this era is similar to that in Mahārāṣtra. It is not, however, known for certain its year actually used to begin. The equivalent Śaka year is obtained by adding 997/998 to its year and the A. D. year by adding 1075/76.

The SIṂHA SAMVAT

This era was in use in *Kathiawaḍ* and *Gujerat*. Inscriptions bearing Samvat numbers 32, 93, 96, 151 of the Siṃha era have been found.***The author is inclined to infer from them that its year is luni-solar and current. The months are amānta but in one instance they seem to be 'Pūrṇimānta.' The year is most probably Āṣāḍhādi. It is certainly neither Kārtikādi nor Caitrādi. By adding 035/36 to the year of the Siṃha era one gets the Śaka year, by adding 1113/14—the A. D. year and by adding 1170 the 'Āṣāḍhādi' Vikrama Sambat.

* Chronological Tables for A. D. 1764-1900 by Giriśa Candra.

** The name, Tribhuvana Malla, has been added on the authority of the *Indian Calen-ar* by Sewell and Diksit. (R. V. V.).

*** Indian Antiquary Vol. XVIII, XIX.

The LAKṢMAṆASENA ERA

This era is current in *Tirhūt* and *Mithila* but always along with the Śaka or Vikrama era. There is a difference of opinion as to its epoch. *Colebrooke* (1796 A. D.) makes its first year correspond with 1105 A. D.; Buchanan (1810 A. D.) fixes it as 1105 or 1106 A. D.; Tirhūt almanacs, however, for the years between 1776 and 1880 A. D., show that it corresponds with 1108 or 1109 A. D. *Buchanan* states that the year begins on the first day following the full-moon day of Āṣāḍha that is on the first lunar day of the dark half of the 'pūrṇimānta' Śrāvaṇa, while Rajendralal Mitra (1878 A. D.) and General *Cunningham* assert that it begins on the first lunar day* of the dark half of (pūrṇimānta) Māgha. Dr. *Kielhorn*, examining six inscriptions dated in this era, from 1194 to 1551 A. D. concludes** that the year of the era is Kārtikādi, that the months are amānta and that its first year corresponds with Śaka 1040-41. This conclusion is supported by *ABUL FAZAL'S* statement in the Akbarnāmā. Accordingly, the Śaka year is obtained by adding 1040-41 to the year of this era, the A. D. year by adding 1118-19 and the 'Kārtikādi' Vikrama Samvat by adding 1175.

The ILĀHĪ ERA

This was established by the emperor *Akbar*. It is also known as the '*Akbar San*'. It dates from his accession, which took place on Friday, the 2nd day of the month of Rabi-us-sani, in Hijrī year 963, i.e. 14th February, 1556, A. D. Śaka 1477.*** This era employed extensively is found on the coins of Akbar and Jahangir, and appears to have fallen into disuse in the reign of Shah-Jahan. Its year is solar. Abul Fazal remarks, "The days and months of this era are both natural solar (Sāvana) without any intercalations. The names of the months and days correspond with the ancient Persian. The months have 29 or 30 days each. There are no weeks, the whole 30 days being distinguished by different names. Some months consist of 32 days†". Here the lengths of the months are said to be "from 29 to 30 days each"; but in the old Persian calendar they had 30 days each. The names of the months in this era, Farwardin etc, are the same as those of the Persian months given in our almanacs at present. The Śaka year is obtained by adding 1476-77 to the Ilāhī year and the A. D. year by adding 1555-56 to it.

The RĀJAŚAKA OR RĀJYĀBHIṢEKA ERA

This was established by *Śivājī*, the founder of the Marāṭhā kingdom and commenced on the day of his accession to the throne, that is on the 13th

* This much information is from Cunningham's "Indian Eras"

** Indian Antiquary, XIX, p. 7 ff.

*** Cunningham has recorded the initial dates of 50 years of Akbar's era as given by Abul Fazal (See Indian Eras, page 225). The first day of the very first year in it, is given as the27th date of Rabi-ul-akhir (Tuesday, 10th March); and the first days of the subsequent years are found to be occurring about 10th March, according to Old Style, that is on the Vernal Equinox day. Thus the first day of the Akbarī era used to fall about the 21st March of the New Style.

Although Akbar ascended the throne on the second day of Rabi-ul-akhir, the commencement of the era was purposely postponed by 25 days. This shows that it was Akbar's intention to start the year on the equinoctial day, that is on the day when the night and day are equal (the day of Sāyana Aries Ingress).

† Prinsep's Indian Antiquities, Useful Tables, II. p. 171.

lunar day of the bright half of Jyaiṣṭha in the Samvatsara named Ānanda, Śaka 1596. The denominating number of the year changes on the above lunar day. In other respects it is the same as the southern luni-solar amānta Śaka years. The Śaka year is obtained by adding 1595-96 to the year of this era and the A. D. year by adding 1673-74*.

The subjoined table gives at a glance the differences in the year numbers of all eras-current as well as obsolete. Of these, the Kali year, however, is given in two ways, current and expired. The year numbers of other eras have, in fact, no differentiation between current and expired. The figures relating to them have been given in this table on the assumption that they represent the number actually assigned to the year in most parts of the country. The commencing month or the day in the case of each era is given in brackets under the name of the era. The lunar months indicated in them are *amānta* moon ending.

Kali (Caitra, Meṣa)	Saptarṣi (Caitra)	Vikrama (Caitra)	Vikrama (Āṣāḍha) (Kārtika)	Christian (January)	Śaka (Caitra, Meṣa)
Expired 4979 Current 4980	4954	1935	1934	1878	1880

Cedi (Bhādra. K. 1)	Gupta Valabhi (Kārtika)	Gupta (Caitra)	Hijrī (Muharram)	Fasalī Deccan (Mṛg, July)	Fasalī Bengali (Bhādra. K. 1
1630	1559	1559	1295	1287	1285

Vilāytī (Kanyā)	Amlī (Bhā S. 12)	Bengalī (Meṣa)	Ārba Sūr (Mṛg)	Harṣa	Magī (Meṣa)	Kollam (Simha, Kanyā.)
1285	1285	1285	1278	1272	1240	1053

Nepal (Nevār) (Kārtika)	Cālukya	Simha (Āṣāḍha)	Lakṣmaṇasena (Kārtika)	Ilāhī (Akbarī) (Sāyana Meṣa)	Śivājī Rāj Śaka (Jyaiṣṭha S. 13)
999	802	764	759	323	204

*In the above discussion, rules for finding the year of an advanced (earlier) era by adding certain numbers to the shorter (later) era have been given, in some cases, two additive figures have been given. The following rule should be observed with regard to them :—

When the day in question is one occurring after the first day of the year of the later era but occurring before that of the earlier era, add the first of the two numbers, otherwise add the second. Examples:—(1) Śrāvaṇa S. 1, Śaka 1801=Śrāvaṇa S. 1, Kārtikādi Vikrama Samvat 1935, Āṣāḍhādi Vikrama Samvat 1936 ; A. D. 1879 (2) Māgha S. 1, Śaka 1801=Māgha S. 1, Āṣāḍhādi and Kārtikādi Vikrama Samvat 1936, A. D. 1880 (3) Śrāvaṇa S. 1, Deccan Fasalī San 1289=Śrāvaṇa S. 1, Śaka 1801, A. D. 1879 (4) Caitra K. 30, Fasalī 289=Caitra K. 30 Śaka 1802, A. D. 1880.

This table gives the year number of each era on Saturday, the 11th lunar day of the bright half of Caitra, Śaka 1800, i.e. 13th April, 1878 A. D. The name of the '*samvatsara*' in that year was Bahudhānya (12th) according to luni-solar system and Vikṛti (24th) according to the Jovian system. The Meṣa Saṃkramaṇa (Sidereal Aries Ingress) had occurred very recently on Thursday, the 9th lunar day of Caitra S. at 10 ghaṭis past midnight, and the Kali year and Śaka year, by the solar measure, had begun, at some places, on the same day, at others, on the next day, or on the third day, that is on Saturday, Caitra S. 11th. In all almanacs, it was the 11th lunar day according to the lunar measure. In Bengal it was the first day of the Saura or solar Vaiśākha (or Meṣa) of the Śaka and the Bengalī San and the 26th day of the Caitra of the Fasalī San. It was the third day of Saura Vaiśākha of the Vilāyatī and Amlī Sans in Orissa. It was the second day of the Saura Caitra i.e. Meṣa in the Tamil (i.e. the Dravidian) country, and the second day of the month of Meṣa of the Kollam (Paraśurāma) year in the North and South Malabar. It was the 9th moon (day) of the month of Rabi-ul-akhir (or Rabi-us-Sani) of the Hijrī era and of the Fasalī and Sūr Sans in our province.

THE LUNAR AND SOLAR MEASURES

Let us consider briefly the use of the two systems of years, viz. the lunar and the solar. Most of our religious rites and festivals have some connexion with the tithi, that is with lunar measure. The ceremonies associated with Saṃkrāntis are related to the solar measure. The years Prabhava, etc. originated from the Jovian measure. Hence, it cannot be stated definitely that a particular kind of measure alone is in use among our people. In some territories, however, the solar measure is mostly in use while in others, the lunar measure. In Bengal, the solar year is in use. The almanac for Śaka 1809 compiled by Jwālāpati Siddhānta and published at Madras, remarks "In these parts the lunar measure is acceptable for the civil life of people; the solar measure is acceptable in the regions, south of Śeṣācalam Hills." I found this almanac with a Tailaṅga Brāhmaṇa residing at *Nellore*, the north of *Madras*, who told me that the lunar measure was in vogue in his part of the country. It appears from this and from several almanacs in use in the Madras Presidency that the author procured and from the information personally gathered from the people of different provinces, for civil purposes, that the solar measure is in use in the Tamil Country of the Madras Presidency, in Malabar and in Bengal; and that in other parts of India, the lunar measure is in use for civil purposes. The measures recommended by scriptures are followed for religious functions. The questions relating to months of this system and their beginning will be considered later on.

BEGINNING OF YEAR

The year began from the month of Madhu in the advent of the spring season, in the times of Yajurveda and later on, throughout the Vedic period. The month of Madhu received the name Caitra at the end of the Vedic period. It appears from the Anuvāk, describing the year-long sacrifice (page 28 of Part I) and from other quotations (pages 29 and 30 of Part I) that the year began with the Citrā full-moon day, (full-moon day of Caitra or the 1st luner day of the dark half), with the Phālgunī full-moon day (i.e. on the 15th lunar day of Phālguna S. or the 1st lunar day of the dark half) and in some cases on the 8th lunar day of the dark half of (ekāṣṭakā of) 'amānta'

Māgha. In one quotation Phālguna is said to be the 'mouth' i.e. the first month of the year (page 131 of Part I). If this Phālguna be a *Pūrṇimānta* month, the 1st lunar day of the dark half of 'amānta' Māgha would be the year-beginning. If it be *amānta* then the 1st lunar day of the bright half of Phālguna would be the year beginning. It is also likely that at one time the year commenced at the beginning of 'pūrṇimānta' Pauṣa ; the month was not, however, called the Pauṣa then (page 134 of Part I). In the Vedāṅga Jyotiṣa period, the year used to begin with the month of 'amānta' Māgha. References can be cited also to show that the year in the Mahābhārata times used to begin in Mārgaśīrṣa ; even then, the references from Sūtras show the importance of the year beginning from Caitra in the 'Vedāṅga' period. Let us now consider the later period. The astronomers begin the calculations in their works either from the initial moment of the solar year or from that of the luni-solar year, according to their convenience. *Gaṇeśa* Daivajña has started the calculations in the *Grahalāghava* from the beginning of the luni-solar* year, but for his work *Tithi-cintāmaṇi* he adopted the solar year beginning i.e. the day of the sideral Aries Ingress as the year beginning. In the case of the solar year too most of the authors of astronomical works adopt the moment of mean Aries Ingress which some adopt that of the true Aries Ingress as the year beginning. Again, in the case of the lunisolar year, the beginning does not necessarily coincide with the first moment of the first lunar day of Caitra Śukla; it is made to coincide with some moment—generally sunrise—on that day. Sometimes the moment of midnight or noon or even sunset is chosen for that purpose.

According to Dharmaśāstras, the year beginning coincides with the beginning of Caitra.

Let us now consider the beginning of the ordinary or civil year. It is needless to say that as religion and practical life are intimately connected, the initial moments of the two kinds of year also have a close relation. In many parts of India the year begins from Caitra. Where the Śaka era and reckoning are in vogue, the year begins from the Caitra Śukla Pratipada. In provinces north of the Narmadā, other than Bengal, the Vikrama era, lunar measure and '*pūrṇimānta*' months are in use. Even then the year begins on the 1st lunar day of the bright half of Caitra. In Bengal, the Śaka era and the solar measure are in use. There the year begins from the Saura Vaiśākha i.e. from the moment of true Meṣa Ingress ; but the importance of the first lunar day of the bright half of the lunar month of Caitra appears to have been recognized. Similarly, the solar measure is in use in the Tamil Country. The year there begins from the moment of true Meṣa Ingress ; still, the importance of the first lunar day of the lunar Caitra Śukla seems to be maintained.

There appears to be a difference of opinion as to whether the year is to begin in the bright half of proper Caitra or that of the intercalary Caitra when Caitra is an intercalary month.

At those places where the year is made to begin from the Meṣa Ingress, it is begun at present from the moment of the true Meṣa Ingress ; but formerly,

* By a luni-solar year is meant that year of which the months are lunar but in which an intercalary month is introduced in order to keep agreement with the solar year.

it seems that it used to begin from the mean Ingress*, because that has importance in astronomical works. The *Bhāswatīkaraṇa* (Śaka 1021) has adopted the moment of true Meṣa Ingress as the epoch. No other work before it had adopted the true Ingress for its epoch. Several instances are found from inscriptions, dated later than Śaka 1083, in Malabar, which show that the month used to begin at the moment of the true Ingress.** *Śrīpati* (Śaka 961) condemns the mean intercalary month and recommends observance of the true inter calary month. It shows that before Śaka 1000, even for civil purposes, the year may have been taken as beginning from mean Meṣa Ingress, and the true Ingress may have come into use later on.

The question as to what moment of the month of Caitra or Meṣa, marked the beginning of the year, will be considered, while discussing the month later on.

The year may also begin in months other than Caitra or Meṣa. Let us consider this question.

The year of the Vikrama Samvat begins on *Kārtika* Śukla Pratipada in some parts of Gujerat and in Southern India. The author has an almanac with him for the Śaka year 1810 (i.e. 1888-89 A. D.) published at *Ahmedabad*. It gives the Vikrama Samvat 1945 as beginning from Āṣāḍha which means that the Samvat year 1945 started from the Śukla Pratipada of *Āṣāḍha* of Śaka 1810. A well-known merchant from Kathiawaḍ, residing at *Barsi*, told the author in Śaka 1810 that for the purpose of maintaining accounts and for other practical purposes they change the Samvat year from the first lunar day of Āṣāḍha Śukla half, in such cities as Rajkot, Jamnagar, Morvi, Tankara, Jodia, Khambhalia, etc. which are situated in the Halar district, and in cities like Amreli, Damnagar, Jetpur, etc., that is, in almost the whole of Kathiawaḍ; and accordingly it was found from the letters received by the merchant from those parts that the Samvat 1944 changed to 1945 after the 1st lunar day of Āṣāḍha Śukla. Dr. *Fleet* also observes in his *Corpus Inscriptionum Indicarum Vol. III*, that the *Halar Samvat* begins from Āṣāḍha. In Śaka 1810 the author met at Barsi some merchants from Idar, who told him that in the territory within 100 miles of their place, the Samvat begins from the 2nd lunar day of the dark half of 'amānta' *Āṣāḍha*. The Fasalī San begins from the first lunar day of the dark half of 'pūrṇimānta' Āśvina (i.e., 'amānta' Bhādrapada) in Bengal and in some parts of Northern India. In Orissa, the year begins from the 12th lunar day of the bright half of Bhādrapada (page 255). It appears that in Tirhut and Mithila, the Lakṣmaṇa Sena era begins from the first lunar day of the dark half of 'pūrṇimānta' Śrāvaṇa or Māgha, which corresponds to amānta Āṣāḍha or Pauṣa.

From the almanacs printed at *Cochin* and *Trivandrum* and from other information, it is learnt that in South *Malabar* and *Tinnevelly* the year begins at the moment of the Sun's entry into Leo. From the almanacs printed at *Calicut* and *Mangalore* and from other sources of informations it is found that in *North Malabar*, the year begins from the *Kanyā* (Virgo) saṃkrānti. In *Madras* Presidency the Fasalī year used to begin with the month of '*Karka*'; later on, it was

* The mean Meṣa Ingress takes place some time after the true Ingress. The difference in the moments of the two is known as 'śodhya' (subtrahend). This 'śodhya' is different in different works. According to Āryabhaṭa I, it is equal to 2 days 8gh. 51 p. 15 vp. and according to modern S. S. it is 2 d 10-14-30.

** *Indian Antiquary, XXV, p.* 53 ff.

made to begin on the 13th of July and at present it begins from the 1st of July. In *Mahārāṣṭra*, the Fasalī year begins with the Mṛga nakṣatra. In Orissa, the year of the Vilāyatī San begins from *Kanyā* Saṃkrānti.

We have so far reviewed the system in use at present. Let us now see the system prevalent in by-gone days. None of our astronomical or other works have either given the history of the first month of the year or discussed the matter or given any decisions. Hence it has become difficult to know the history of this question at present. *Ś*ivājī's coronation era used to begin from the 13th lunar day of the bright half of Jyaiṣṭha. The Akbarī San used to begin with the tropical Meṣa saṃkrānti that is the vernal equinox day. According to *Kielhorn,* the *Cedi* era began in Āśvina. *Albiruṇī* has given very valuable information on this point. He writes :

"The astronomers who use the Śaka era, begin the year with the month Caitra, whilst the inhabitants of Kanir, which is conterminous with Kashmir, begin it with the month Bhādrapada.

All the people who inhabit the country between Bardārī and Mārīgala begin the year with the month Kārtika......The people living in the country of Nīrahāra, behind Mārīgala, as far as the utmost frontiers of Tākeśar and Lohāvar begin the year with the month Mārgaśīrṣa......The people of Lanbaga, i.e. Lamghān, follow their example. I have been told by the people of Multan that this system is peculiar to the people of Sindh and Kanoj, and that they used to begin the year with the new moon of Mārgaśīrṣa, but that the people of Multan only a few years ago had given up this system, and had adopted the system of the people of Kashmir ; and followed their example in beginning the year with the new moon of Caitra."*

According to the amānta lunar measure the year beginnings are as follows :—(1) The beginning of the month of Madhu (The 1st lunar day of the bright half of Caitra (2) the 1st lunar day of the dark half of Caitra, (3) the 13th lunar day of Jyaiṣṭha Śukla. (4) The 1st lunar day of the bright half, and first and second lunar days of the dark half of Āṣāḍha (5) the 1st and 12th days of the bright half and the 1st day of the dark half of Bhādrapada. (6) Perhaps the 1st lunar day of Āśvina Śukla (7) the 1st lunar day of Kārtika Śukla and that of the dark half of 'amānta' Kārtika (8) the 1st lunar day of Mārgaśīrṣa *Ś*ukla (i.e. beginning of the month of Mārgaśīrṣa), or perhaps, the 1st lunar day of the dark half of Mārgaśīrṣa (i.e. the beginning of the month of 'pūrṇimānta' Pauṣa); (9) the first lunar day of the dark half of pauṣa, (10) the 1st day of the bright half of Māgha and perhaps the first day of the dark half of Māgha (i.e. the beginning of the 'pūrṇimānta' Phālguna), the 8th day of the dark half of Māgha, and (11) sometimes the 1st lunar days of the bright and dark halves of Phālguna. According to the Nirayaṇa solar measure the year beginnings are :—(1) Meṣa Ingress (2) the Mṛga nakṣatra (approximately the 25th day of the month of Vṛṣabha) (3) Sun's Ingress into Karka, Siṃha and Kanyā. These occur respectively in the amānta lunar months of Caitra, Jyaiṣṭha (sometimes Vaiśākha, Āṣāḍha, Śrāvaṇa, and Bhādrapada.) By the tropical (Sāyana) solar measure the first point of Aries and the 1st day of July (approximately the 11th day of the tropical Cancer Ingress) marked the year beginnings.

* Albiruṇī's India, Vol II. p 8

Let us now see when and where these year-beginnings were or are in use. The beginning of Madhu or Caitra in the spring season is regarded as the beginning of the year by Śrutis, Vedāṅgas, Smṛtis, Purāṇas, works on astronomy and the modern and ancient works on Dharmaśāstra. Copper plate and other inscriptions of Gupta-Kings during the period from 156 to 209 of Gupta era, Śaka 397 to 450, have been discovered. All astronomical references in them can be verified when the year is taken to begin from the beginning of Caitra.* At one time the Guptas enjoyed suzerainty over most of Northern India. Beruṇī has written (Śaka 952) that the beginning of Caitra marked the beginning of the year. In short, this year beginning has been universally recognized at all times and in all places. Even when this year beginning was in use, there had been and still are other year beginnings at some places and at some times. The first day of the dark half of Caitra, which always occurred in the spring season, appears to have been regarded as the year-beginning by the pūrṇimānta scheme at some places during part of the Vedic period. In Bengal, the year begins at the beginning of the solar month of Vaiśākha i.e. at the beginning of Meṣa. Its antiquity cannot be ascertained. It is, however, recorded in the works on Dharmaśāstra by Jīmūtavāhana current in Bengal; and this Jīmūtavāhana appears to have lived about Śaka 1014.** The *Bhāsvatīkaraṇa* (Śaka 1021) which was compiled in the holy city of *Jagannātha* makes the year beginning coincide with the Meṣa Saṃkrānti. Again the same, that is, the beginning of the solar Caitra, is taken to be the year beginning in *Tamil* region; and it is also not known how ancient the practice is. But copper plates and other inscriptions belonging to the 12th century of the Śaka era have been found*** in those parts, which refer to the solar months. The Ārya-siddhānta is in use in that region. This year beginning may have been as old as that work (Śaka 421). The sun enters Mṛga nakṣatra in the month of Jyaiṣṭha and sometimes in Vaiśākha. This is the time of the year beginning of the *Sūr San* and the *Fasalī San* in Mahārāṣṭra and the adjoining territories. This has been in vogue from Śaka year 1266 (1344 A.D.). This accords the seasonal year. The New year's Day following the 13th lunar day of bright half of Jyaiṣṭha has a personal association, since it is the first day of the regular year of *Śivājī*. The year begins on the 1st lunar day of bright half of Āṣāḍha in use in Kathiawaḍ and the practice is at least as old as the Siṃha Saṃvat, (Śaka 1036). Similarly choice of the 2nd lunar day of the dark half of Āṣāḍha appears to be equally old. The 1st lunar day of the dark half of Āṣāḍha as the year-beginning connected with the *Lakṣmaṇa Sena* era, in Tirhut and *Mithila* may have come into use some time after Śaka 1041. Although all the three year-beginnings in Āṣāḍha are connected with tithis, still they are essentially seasonal since they are clearly related to the beginning of rains. The Fasalī San formerly used to begin with the beginning of *Karka*, that is, in Āṣāḍha in the Madras Presidency; but at present, under Government orders it begins from the 1st July (in Jyaiṣṭha or Āṣāḍha). This also is seasonal. Now-a-days the Official Revenue year begins in August in our province. (The official year begins also in April. The civil year begining in January is now current everywhere.) In *Malabar* the year begins at the beginning of Siṃha (in Śrāvaṇa) and that of *Kanyā* (Bhādrapada). The practice may be as ancient as the Kollam era (Śaka 747). In Bengal the year begins at the beginning of 'Kanyā'. This is associated with the Fasalī San and has come into use from *Akbar's* time. In

**Gupta Inscriptions*, Introduction.

***See* Chapter on 'Māsatatva' in the work entitled, *Kālatatvavivecana*.

****See* my *Indian Calendar*, p. 89.

Albiruṇī's time, the year used to commence in Bhādrapada in the vicinity of Kashmir. The 12th day of the bright half of Bhādrapada has a personal association in Orissa in regard to the new year. The first day of the Cedi year probably used to fall on the 1st lunar day of the dark half of Bhādrapada. It may as well have been the 1st day of the bright half of Āśvina. Copper plate inscriptions from the Cedi year 793 (Śaka year 962) have been found and the practice may be reaching as far back as that year. The choice of Kārtika as the year-beginning appears to be very ancient. Bhaṭotpala's commentary on the Bṛhatsaṃhitā contains some quotations from earlier authors of the Saṃhitās, wherein there are stray references of all the months; in the course of these, Kārtika has been mentioned as the first month of the year at certain places. In the Sūrya Siddhānta also it has been spoken of as the first month. It appears to have been in vogue in Northern India from the date of Vikrama era. A number of copper plates and other inscriptions from the Vikrama year 898 onwards have been found in Northern India in which the Vikrama Samvat has been mentioned as commencing from Kārtika. At the time of Albiruṇī, the Vikrama year was Kārtikādi. Even in Nepal, the Kārtikādi year was current till 1748 A.D. At present it is confined only to Gujerat. The month of Kārtika got the first place in the order of months because Kṛttikā was regarded as the first nakṣatra. Even the years beginning from Mārgaśīrṣa appears to have some connection with Kṛttikās. Apparently that month was regarded as the first which began on the day following the full moon with Kṛttikās, the first nakṣatra, but the month was named Mārgaśīrṣa since it would end with the full moon near the Mṛgaśirṣa star. The months referred to in the *Mahābhārata* are Mārgaśīrṣādi and not Kārtikādi. This shows that the system of reckoning months from Mārgaśirṣa is more ancient than the Kārtika-system. It must have been in use as far back as 2000 B.S. At the time of Alberuṇī, Mārgaśirṣa was the year-beginning in many regions. It is not in use now. Considering the name Agrahāyaṇī applied to Mṛga-śirṣa, it appears that when that star was the first nakṣatra about 4000B.S., they used to begin the year from the day following the full moon near that nakṣatra. Had the system of naming months as Pauṣa, etc., been in existence, the first month of the year would have been called Pauṣa. But it was not existent; and hence, no reference to the names Pauṣa, etc., is found anywhere. Its absence is one of the proofs to show that the names Caitra, etc., came into use after Kṛttikā became the first nakṣatra. The first lunar day of the dark half of Pauṣa may have been the first day of the year of the Lakṣmaṇasena era some time in Bengal. The beginning of the year is recorded in the Vedāṅga Jyotiṣa as coinciding with the beginning of Māgha. It seems that it was not in use in wide areas for a long time. The year-beginning referred to in the quotation "Phālguna is the first month of the year" (page 131 of Part I) must have been the first lunar day of the dark half of Māgha or that of the bright half of Phālguna. This was probably meant for restricted use. The 8th lunar day of the dark half of Māgha (Ekāṣṭakā) as the year beginning seems to be likewise restricted in use, for it has not been prescribed as the first day of the year-long sacrifice, [All Mīmāṃsakas believe that the anuvāk relating to the year-long sacrifice has been construed by Jaiminī as directing that the sacrifice should begun 4 days before the full moon day of Māgha.] The same thing is corroborated from the fact that Āśvalāyana has recommended the full moon of Phālguna or Caitra (page 136 of Part I) for commencing the sacrifice. The Phālgunī full moon day has been recommended as the year beginning because of its association with Spring (page 136 of Part I). It is, however, already pointed out before (page137 of Part I) that in the Vedic period, the equinox did not occur in Phālguna.

There is no amānta lunar month which was not associated, at some time or other, with the beginning of the year. But of all the months, Caitra has the strongest link with the year beginning ; Kārtika and Mārgaśīrṣa have got comparatively lesser association with it, still it is fairly strong. Bhādrapada can claim much less, yet it is considerable. Jyaiṣṭha, Āṣāḍha, Śrāvaṇa, Māgha and Phālguna have only a slight relation with it while Vaiśākha and Āśvina have slighter still.

Almost all the types of year-beginnings described above have seasons as their underlying cause.

There used to be in the past and there are even now different year-beginnings in the same region and at the same time. For instance, in our province, we have these days different year-beginnings like the 1st lunar day of the bright half of Caitra, Mṛganakṣatra, the first lunar day of the bright half of Kārtika, January, etc. In each province there are at least two year beginnings.

FIRST POINT OF THE ZODIAC

The foregoing discussion does not show that the year beginning in a particular month, receded to the previous month gradually. The cycle of nakṣatras begins from the Kṛttikās according to the *Vedāṅgas*. One may naturally infer that Mṛga was the first nakṣatra before the Kṛttikās. But no such system of reckoning is actually found to have been in use. Astronomical works like the *Siddhāntas* give Aśvinī as the first nakṣatra. It was not so in the *Vedic or Vedāṅga-Jyotiṣa periods*. According to the Vedāṅga Jyotiṣa, the cycle began from the Dhaniṣṭhās. According to the Mahābhārata, Śravaṇa was once the first nakṣatra; which means that these two stood at the head of the nakṣatras in the Vedāṅga period; and in that period, Kṛttikā also was regarded as the first nakṣatra. The priority of Mṛga, Kṛttikā and Aśvinī was related to Spring or the vernal equinox and that of Dhaniṣṭhā and Śravaṇa to the winter solstice.

There does not appear to be a tradition that the leadership of the nakṣatra-cycle should successively pass on to each preceding nakṣatra.

JOVIAN YEAR

SAMVATSARA

The word Samvatsara was originally used in the sense of year. But there is a system of assigning names like Prabhava, etc., to 60 years in order. The term Samvatsara is affixed to these names also. These samvatsaras originated from Jupiter's movement and that is why they are called Jupiter's years or Jovian years. They must have come into being, after it was known that Jupiter takes about 12 years for one revolution through the zodiac. The time taken by the sun to make a complete round is known as year, while the 12th part of this period is called a month. Following the same line of reasoning, the system of naming the period for one revolution of Jupiter as Jovian year and its 12th part as Jovian month must have first come into use. Just as the lunar months derived their names Caitra, etc., from the moon's position in the nakṣatras, Jovian months too must have derived their names from the nakṣatras with which Jupiter was every time observed when heliacally rising, since it

vanishes for some days in the light of the Sun owing to its proximity with the Sun. These Jovian months are, in fact, nothing but solar years; and that is why the years came to be called Caitra Samvatsara, Vaiśākha Samvatsara and so on. The twelve year cycle is a convenient means for measuring the number of years. This twelve year cycle is of two kinds. In one, the Samvatsara receives its name from Jupiter's (heliacal) rise; let this system be called "Udayapaddhati" (the rise system). About 400 days elapse between two consecutive (heliacal) rises of Jupiter and during the period of one revolution, that is, in 12 years, Jupiter rises (heliacally) 11 times and one samvatsara is, therefore, suppressed. This system is somewhat inconvenient. Hence, when Jupiter's mean motion was correctly known, astronomers decided to call that period Jovian year, in which it passes through one-twelfth part or one sign of the zodiac. By this system, no samvatsara is suppressed during 12 years. Let us call this system the mean sign system (Madhyama-Rāśi-paddhati). It is not so natural and easy to know the time Jupiter takes to pass through one sign by mean motion, as it is required to see and know the actual rise of Jupiter. It appears from this that the Udayapaddhati must have been the original* system. References from the Mahābhārata indicate that it may have been in use before 500 B.S. The Caitrādi samvatsaras are not known in our province, but the Cāndra Pañcāṅga of the Marwaris States the name of the Samvatsara, such as Caitra Samvatsara, etc., as calculated by the mean sign-system. Similarly, in Madras Presidency, the Telugu almanacs of the lunar system give the names of samvatsaras according to the 'Udaya-paddhati'. Among the several ancient inscriptions on stones and copper plates that have been found so far there are five belonging to the period from Śaka 397 to 450 when the Guptas were in power. These inscriptions bear witness to the use of Caitra and other Samvatsaras. (It has been proved that the samvatsaras have been calculated by the 'Udaya' system.) Similarly two inscriptions, belonging to the king Mṛgavarmā of Kadamba dynasty of South India have been found which refer to such samvatsaras.

SIXTY SAMVATSARAS

The Vedāṅga Jyotiṣa refers to a yuga consisting of five years. Apparently this led to the conception of an analogous period (yuga) consisting of five Jovian years. This cycle naturally consisted of about 60 years, and its years (samvatsaras) were named Prabhava, etc. Thus came into existence the cycle of sixty years. It must, of course, have originated after the twelve year cycle. It is more convenient for counting the number of years. In the beginning, the samvatsara in this cycle also used to be reckoned from the (heliacal) rises of Jupiter; but later on the system was abandoned and replaced by that of calculating the years from the time taken by Jupiter to pass through a sign by mean motion. According to the Sūrya Siddhānta, Jupiter takes† approximately 361^{d}—1gh—36^{p} to cross one zodiacal sign. This length of the Jovian year is somewhat less than that of the solar year. Hence, there occur 86 Jovian years during a period of 85 solar years which necessitates the suppression of one Jovian year. It is similarly evident that the Samvatsara may begin at any moment during the year. The Jovian samvatsara has another system of reckoning in which no samvatsara is suppressed, which virtually amounts

*I have discussed this subject in detail in the article "Twelve-year cycle of Jupiter" in two issues of the English monthly entitled *Indian Antiquary*, for the year 1888.

†A few palas more or less according to other siddhāntas.

to adopting for this samvatsara a length equal to that of the solar year ; and hence, such a samvatsara is termed a Saura (solar) samvatsara, or a Cāndra (lunar) samvatsara in virtue of the fact that it begins on the same day as the lunar year. At present the Jovian samvatsaras are in use in regions north of the Narmadā ; and the lunisolar samvatsara system is in use in the south. The Samvatsaras prevalent in Southern India (south of the Narmadā) are also called Jovian by some ; but it is a mistake. There is no "Jovianity" left in them at present.

LUNI-SOLAR SAMVATSARA

The system current in the South is not the original system. The luni-solar system has been mentioned in the modern Romaśa siddhānta and Śākalya's Brahmasiddhānta ; but these works are not as old as other siddhāntas. All other siddhāntas have referred only to samvatsaras belonging to the Bārhaspatya (Jovian) system. The astronomical works describe 'sāvana' (civil) and other different kinds of measures and among these the Jovian (measure) is expressly mentioned as specially to be used in the case of samvatsaras. Copper plate and other inscripions show that even in the South the Jovian system of reckoning samvatsaras was formerly in use. For example, a copper plate inscription relating to king Govinda III* of Rāṣṭrakūṭa dynasty has bee found, which is dated Thursday, the fifth lunar day of the dark half of Vaiśākha, in Subhānu Samvatsara, Śaka year 726. Calculation shows that if Śaka 726 be supposed to be the expired year the 5th lunar day of the dark half of 'amānta' Vaiśākha fell on Friday the 3rd of May 804 A.D. and by the 'pūrṇimānta' system, it fell on Thursday, 4th April 804 A.D. which shows that the date of the inscription would be confirmed if the 'pūrṇimānta' system be followed. The date cannot be verified if Śaka 726 be regarded as the current year.

JOVIAN YEAR IN SOUTH

According to the system now prevalent in the South, the Śaka year 726 would be Tāraṇa samvatsara which is the 18th of the series. But the inscription mentions Subhānu (the 17th) as the samvatsara. According to the true Jovian system of reckoning samvatsaras which are in use in Northern India (north of the Narmadā), the Subhānu samvatsara began on Saturday, the 9th lunar day of the dark half of Adhika Āṣāḍha in (expired) Śaka year 725, *i.e.* on 17th June 803 and the Tāraṇa samvatsara, later on started on Wednesday the 1st lunar day of the bright half of Āṣaḍha, 12th June, 804, which shows that the Subhānu samvatsara was current on the date of the inscription. It would appear from this that the correct system of Jovian measure was in vogue in the South up to Śaka 726 ; or at any rate it was in vogue in the territory on the banks of the Tungabhadrā where this inscription was found. Such other instances are also available. The true Jovian samvatsara does not commence on the 1st lunar day of the bright half of Caitra and the system calls for the suppression of a samvatsara once in every 85 years. It is but natural that there should be a tendency to abandon this complicated system and to accept the simpler system of beginning the samvatsara along with the lunar or the solar year. It may be due to this or to negligence in suppressing one year in 85 years that the system now prevalent in the South has come into vouge ; and it is evident that the luni-solar system must have come into vogue in the South at a time when the samvatsara according to the Southern system

*See Indian Antiquary Vol. XI, p. 126.

happened to be the same as that found by the true Jovian measure. Both the systems gave the same samvatsara during the period from Śaka 743 to 827. Later on, the people in the north followed the system of suppressing one samvatsara according to rules and those in the South discontinued it, with the result that the Southern samvatsara began to lag behind. At the beginning of the Śaka year 1818, the samvatsara in the South is the 30th, named Durmukha, while that in the North is the 42nd, called Kīlaka. In short, the luni-solar samvatsara system came into vogue in the South from Śaka 827.

PŪRṆIMĀNTA AND AMĀNTA MONTHS

(Full moon ending and New moon ending months.) It has been already shown (page 33 of Part I) that in the Vedic period both kinds of month—full-moon ending and new moon ending—were in use. At present the system of full moon ending months is followed on the northern side of the Narmadā and that of new moon ending (amānta) months in the south. But for certain religious observances like the holy bath of Kārtika, people in the South also follow the 'pūrṇimānta' system. The example of Śaka 726 given above in our study of the sixty-year cycle will show that the 'pūrṇimānta' system was in everyday use in the Deccan or at least up to the Tuṅgabhadrā. Instances of this sort belonging to an earlier period also are available. There is a copper plate inscription* of Mādhavācārya (Vidyāraṇya) the Minister of King Harihara, which contains the expression "at the holy moment of the solar eclipse on Wednesday, the Newmoon day of Vaiśākha in Śaka 1313". The solar eclipse and Wednesday, referred to in this, happen to be true only if Vaiśākha is reckoned by the 'pūrṇimānta' system and not by the 'amānta' system. This shows that in South India the 'pūrṇimānta' system was in use on some occasions even in the 14th century of the Śaka era.

Although it is true that the 'pūrṇimānta' system of months is followed at present in northern India, the 'amānta' system is followed for naming the months and determining the intercalary month. Further description about this is made later on. It is needless to add that the consideration of pūrṇimānta and amānta systems is out of question where solar months are observed.

NAMES OF MONTHS AND INTERCALARY MONTHS

Caitra and other names of months first originated with the names of Citrā and other stars, that is to say months began to receive names from those stars near which the Moon becomes full. But it is not that the Moon always becomes full near the star Citrā in Caitra. It may become full sometimes near Citrā, sometimes near Svatī and sometimes near Hastā. Hence it was found necessary to make a rule in this respect that when the moon would be found full near one of a pair of nakṣatras, starting from Kṛttikā-Rohiṇī, the months should be named Kārtika, Mārgaśīrṣa and so on. In this grouping the months of Phālguna, Bhādrapada and Āśvina had a triad of nakṣatras assigned to each. †Even by following this rule sometimes a month receives an unwanted name. Thus, for instance, according to the Grahalāghava almanac, there was Śravaṇa nakṣatra at the end of the fullmoon day of Āṣāḍha of Śaka 1815. From this position the month ought to have received the name Śrāvaṇa. It has been also found by calculation that even by supposing a nakṣatra

Memoirs of Savantvadi State, p. 287.

†*See* S. S. Mānādhikara, Verse 16. A more detailed exposition would be found in my article "Twelve-year cycle" in the January 1888 issue of the *Indian Antiquary*.

to consists of 800 minutes, the intercalary and suppressed months would occur quite often and that too not regularly according to a fixed rule*. Again, as the stars related to the nakṣatras are not situated at regular distances, greater disorder would take place. However, this system may have continued for some time by following the rule approximately, that is, by avoiding the frequency of intercalary or suppressed months and this system may have remained in use till the moon's motion was very accurately determined. The Vedāṅga Jyotiṣa gives tolerably accurate motion of the moon and from that time this mode of reckoning may have fallen into disuse. According to the Vedāṅga Jyotiṣa system, an intercalary month occurs after every 30 months ; but it has been shown in our study of Vedāṅga Jyotiṣa that this rule also may have been soon discarded because it was not very accurate, and it might have been replaced by the system of introducing an intercalary month after every 32 or 33 months. The Pitāmaha Siddhānta mentions the system of inserting an intercalary month after every 32 months. The (position of the) intercalary month could be correctly calculated after accurate siddhāntas like the Sūrya-Siddhānta of the Pañcasiddhāntikā were compiled. The modern rule for naming the (lunar) month is to name that lunar month as Caitra in which the true Meṣa Saṃkrānti would occur, to name that one as Vaiśākha in which the true Vṛṣabha Saṃkrānti would occur and so on. The lunar month in which no saṃkrānti would occur is to be treatd as intercalary and that in which two saṃkrāntis would fall is to be treated as 'suppressed'. But we come across two kinds of definitions about them. One of them is :—

मेषादिस्थे सवितरि यो यो मासः प्रपूर्यते चांद्रः चैत्राद्यः स ज्ञेयः पूर्तिद्वित्वेऽधिमासोऽन्त्यः ।।

These lines are attributed to the Brahmasiddhānta. But they are not found either in the Siddhānta of Brahmagupta or of Śākalya. They are, however, found in the 'Kālamādhava' by Mādhavācārya (Vidyāraṇya) and the work belongs to Śaka 1300 *circa*. The lines mean that the lunar month which ends when the sun is in Meṣa (Aries) is to be called Caitra (all other months are to be named similarly). If two lunar months are found ending in the same solar month, then the second of them is to be called an intercalary month. (It is to be named according to the foregoing rule.) The second rule is found in a work on Dharmaśāstra entitled "Kālatattvavivecana" †where it is attributed to Vyāsa ; it is as follows :—

मीनादिस्थो रविर्येषामारंभप्रथमे क्षणे ।। भवेत् तेऽब्दे चांद्रमासाश्चैत्राद्या द्वादश स्मृताः ।।

"That lunar month at the commencing moment of which the sun is in Mīna is to be called Caitra, and all the 12 months beginning with Caitra are to be named in this way."

All months except the intercalary and suppressed months receive the same name by both the rules ; but the names of intercalary months vary. Suppose, for instance, the Meṣa Saṃkrānti occurred on the fourteenth lunar day of the dark half of a lunar month, there was no saṃkrānti in the next month and the Vṛṣabha saṃkrānti occurred on the 1st lunar day of the bright half of the 3rd month; and the Mithuna saṃkrānti occurred on the 2nd lunar day of

*The calculation is not given here for want of space.

†There is a copy of this work in the Ānandāśrama, Poona (No. 4413). The date of its compilation is Śaka 1542.

the bright half of the next lunar month. As the first and the third lunar months ended when the sun was respectively in the Meṣa and Vṛṣabha signs, they are, by the 'Meṣādisthe' rule to be named Caitra and Vaiśākha. Even by the "Mīnādistho" rule, these months had the sun's position respectively in the signs Pisces and Aries at the moment of their beginning ; they are to be called Caitra and Vaiśākha. The second month was a "non-Saṃkrānti" month. It was, therefore, intercalary by either rule. However, as it ended when the sun was in Meṣa (Aries), it received the name Adhika Caitra according to the rule "Meṣādisthe" and as the sun was in Meṣa, when it commenced, it received the name Vaiśākha according to the rule, "Mīnādistho". The second system is at present universally in use. By this rule, the intercalary month receives the name of the next month, while the first rule gives that of the preceding month. That the system prevalent at the time of Bhāskarācārya was the same as at present is proved by the following observations made by Bhāskarācārya in his commentary on the verse "Asaṃkrāntimāso....etc." from the Chapter on "Mean Motions". After first observing that a suppressed month is preceded and also followed by an intercalary month, each separated by 3 months on either side, he adds : "Formerly there was a case in which Bhādrapada was an intercalary month, then Mārgaśīrṣa was declared a suppressed month, and it was again followed by an intercalary month which was Caitra". Similarly, the present system was prevalent at the time of the Kālamādhava also, since that work contains the statement of the intercalary months in the Śaka year 1259, Īśvara Saṃvatsara, was Śrāvaṇa, which accords with the present system of naming the intercalary month. That intercalary month would have received the name Āṣāḍha if the 'Meṣādisthe' rule had been followed. That the 'Meṣādisthe' rule was in force for some time is seen from a copper plate inscription. But more is given about it later.

MEAN AND TRUE INTERCALARY MONTHS

At present a month is declared as intercalary or suppressed from the sun's true entry into a zodiacal sign. But it appears that the system of determining the intercalary month by mean motion was also in use at one time. The mean motion is always the same. According to that measure the intercalary month occurs after 32 lunar months, 16 tithis, 3 ghaṭis and 55 palas, that is sometimes after 32 months and sometimes after 33. Again, as the length of the mean solar month is 30 days 26 gh. 18 pals and that of the mean lunar month is 29 days 31gh. 50 pals, two saṃkrāntis can never fall in one lunar month by the mean measure, and hence a suppressed month can never occur. The true motion of the Sun is never the same ; hence, the length of the true solar month always varies, and two solar ingresses sometimes take place in the same lunar month ; and hence, a suppressed month does occur. When in a particular year, there is a suppressed month, two intercalary months also occur in that year. By true motion, the minimum interval between two intercalary months is 28 months* and the maximum is 35 months. There is a copper plate inscription of Dharasena IV from Kheḍā (Kaira), dated the second lunar day of (the second) Mārgaśīrṣa, Samvat 330 of the Gupta Valabhi era. The word 'second' in this clearly shows that Mārgaśīrṣa is intercalary. In the Guptavalabhi Samvat 330, Śaka 570, Kārtika is found to have been an intercalary month by true motion ; but by the mean motion system and by the 'Meṣādisthe' rule Mārgaśīrṣa would prove to be intercalary. The fact

*On rare occasions it is only 27 months. Jyaiṣṭha was intercalary in Śaka 1311 and Bhādrapada in Śaka 1313.

that Mārgaśīrṣa has been recorded in the inscription as intercalary cannot be explained by any other theory. It follows, therefore, that in Gujerat, they used to determine the intercalary month by mean motion system and to denominate it by the 'Meṣādisthe' rule in Śaka 570. Some astronomical works too show that the mean motion system for determining the intercalary month was in use. The following is an extract from Śrīpati's work Siddhānta Śekhara (Śaka 961), cited in Jyotiṣa-darpaṇa, a Muhūrta work :—

मध्यमरविसंक्रमयोर्मध्ये मध्यार्कचंद्रयोर्योगे । अधिमासः संसर्पः स्फुटयोरंहस्पतिर्भवेत् योगे ॥
मध्यग्रहसंभूतास्तिथयो योग्या न संति लोकेऽस्मिन् । ग्रहणं ग्रहयुद्धानिच यतो न दृश्यानि तज्जानि ॥

रविमध्यमसंक्रांतिप्रवेशरहितो भवेदधिकः । मध्यश्चाद्रो मासी मध्याधिकलक्षणं चैतत् ॥
विद्वांसस्त्वाचार्या निरस्य मध्याधिकं मासं । कुर्युः स्फुटमानेन हि यतोऽधिकः स्पष्ट एव स्यात् ॥

This clearly shows that the system of determining the intercalary month by mean motion was once prevalent. Bhāskarācārya has mentioned the suppressed month. A suppressed month is not possible by the 'mean motion' system. This shows that in his time the system had gone out of use. It may have totally disappeared about Śaka 1000.

The English book, *Indian Calendar**, written by Robert Sewell and myself contains a list of intercalary months between 300 and 1900 A.D as calculated by the true motion system and those between 300 and 1100 A.D as calculated by the mean motion system.

INTERCALARY MONTHS, NORTH OF THE NARMADĀ

Although in the present times, the months are reckoned as full moon ending, intercalation and the names of intercalary months are regulated by the 'new-moon ending' system of months ; and for this reason, the bright halves of (lunar) months receive the same name in both the regions while in the north the dark half receives the name of the month next to the one current in the South. For instance, the Caitra bright half bears the same name in both the regions but the dark half known as Caitra Kṛṣṇa in the Deccan is called Vaiśākha Kṛṣṇa in the North, irrespective of when the saṃkrānti occurs. But the following table would give an idea as to how the true system of full-moon ending months would operate :—

True Pūrṇimānta rackening	Sun's entry into Sign	Half Months	Sun's entry into Sign	True Amānta Reckoning
		1. BRIGHT		
PHĀLGUNA			Meṣa Ingress	CAITRA
		2. DARK		
CAITRA	Meṣa Ingress			
		3. BRIGHT		
				INTERCALARY
		4. DARK		
VAIŚĀKHA	Vṛṣa Ingress			
		5. BRIGHT		
			Vṛṣa Ingress	VAIŚĀKHA
		6. DARK		
JYAIṢTHA	Mithuna Ingress			
		7. BRIGHT	Mithuna Ingress	JYAIṢTHA

This table will show that the system of true 'pūrṇimānta' months would not give an intercalary month in this case, because the sun entered a new sigan in each month ending with the full moon. But according to the amānta

*This book was recently published in England, in June 1896.

month system, the third and fourth half-months constitute an intercalary month ; and hence the same would be regarded as intercalary in the territories to the north of the Narmadā. It is interesting to note that the intercalary month is preceded and followed by a half-month of the "śuddha" (*i.e.* a non intercalary) type. Thus in the above table, the second half is the 'proper' (*i.e.* non-intercalary) dark half of Vaiśākha, the 3rd and 4th halves belong to the intercalary month, and the 5th half again belongs to the 'śuddha' (*i.e.* non-intercalary) Vaiśākha Śukla*. This is the system at present in use. But it has been shown in our study of the Pañcasiddhāntikā, that at the time of Varāha Mihira, that full-moon ending month was termed Caitra, in which the Sun's ingress into Aries took place, no matter whether it occurs in the bright or dark half.

BEGINNING OF MONTHS

The beginning of a tithi and the ingress of the sun into a new sign may occur at any moment of the day and the lunar and solar months actually begin at these very moments respectively. But it is convenient for practical purposes to reckon the beginning of the month as from sunrise ; and hence, the lunar month is supposed to begin on the day on which the first tithi is current at sunrise. If the first tithi is current at the moment of sunrise on two consecutive days, then the beginning (of the month) is supposed to have occurred on the first of the two days. Different rules as regards the beginning of the solar months are observed. They are :—

1.(a) In Bengal, if the ingress takes place between sunrise and midnight, they observe 'parvakāla' (holy period) on that day and begin the new month the next day. If the ingress takes place between midnight and the *next* sunrise, the 'parva' is observed the next day and the month begins on the *third* day.

(b) In Orissa, the months of the 'Amlī' and 'Vilāyatī' Sans begin on *the day* of the sun's ingress whatever be its time.

(2). Two different rules are followed in Madras Presidency also. (a) In Tamil country, if the ingress takes place before sunset, the month begins on the *same day*; but if after sunset, it begins on the *next day*. (b) In Malabar, if the ingress takes place before aparanha *i.e.* within the first three (out of five) parts of the day' the month begins on the *same* day, otherwise on the *next* day†.

The four rules have been deduced after studying the almanacs current in these parts and from other information ; but it is not that there can be no exceptions to them. Thus in a Tamil almanac for Śaka 1815, published at Madras, the rule observed was that the month should begin on the *same* day, if the ingress takes place before midnight, otherwise, on the *next* day. A set of

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*In order to avoid this apparent disorder of names, the month consisting of the 2nd and 3rd halves, in this example, would be called first Vaiśākha and that consisting of the 4th and 5th halves called the 2nd Vaiśākha.

†In a temple at Kannanur'a village 5 miles north of Srirangam near Trichinopoly, there is a stone inscription of Śaka 1193. It has been proved that its date involves one of the rules mentioned in 2 (a) and (b) above. See Epigraphia Indica Vol. III, p. 10.

CHRONOLOGICAL TABLES is every year published under the authority of the CALCUTTA HIGH COURT. In the Table for 1882-83 A.D. the months of the Vilāyatī San are shown to begin according to this rule.

PARTS OF THE PAÑCĀṄGA

Let us now consider the FIVE MAIN FACTORS of the Pañcāṅga (almanac) *Tithi* (lunar day), *Vāra* (day of the week), *Nakṣatra* (asterism), *Yoga* (sum) and *Karaṇa* (half tithi)-these are the five factors of the almanac. When the sun and the moon come together in the heavens, that is, when their longitudes are the same, the "amāvasyā" (the 30th tithi) is said to end. Thereafter, as the motion of the moon is greater than that of the sun, the moon goes ahead of the sun. The time required by the Moon to gain 12° over the Sun is termed *tithi* (a lunar day) ; hence, during the period necessary for the Sun and the Moon to come together again, that is, in a lunar month, there occur 360÷12= 30 tithis. The time taken by the moon to go 6° ahead of the Sun is termed *Karaṇa*. The days of the week are reckoned from sunrise to sunrise. Each part obtained by dividing the zodiac into 27 parts of 800 min. of are cach, and also the time taken by the moon to cross the part, is termed *Nakṣatra*. Yoga is the time required for the sum of the longitudes of the sun and moon to increase by 800 minutes.

WHEN DID THE FIVE PARTS COME INTO USE ?

Our people are accustomed to making almanacs (Pañcāṅgas) from very ancient times. It would not be wrong to assume that the almanac has been in use ever since the people began to have a little knowledge of astronomy. It is obvious, however, that the almanac in use in ancient times could not have been exactly like the one of the present days. Instead of being quinquepartite as at present, the almanac may as well have been quadripartite, tripartite, bipartite or, so to say, even unipartite ; and they must have been imparting the necessary knowledge verbally, before any script was invented. But something indicating astronomical positions must have been in use in some form or other from very ancient times. Let us now denote that form by the name Jyotirdarpaṇa (Mirror of the Heavens). Even the Vedas ordain that certain rites should be performed on a certain day, or nakṣatra or in a particular season. From this it is clear that Jyotirdarpaṇa is very ancient. Its first factor or part is the *sāvana* day. At present *vār* (day of the week) has been substituted for the sāvana day. The knowledge of nakṣatras developed after that of the sāvana day and then *nakṣatra* became the second factor. Later on there arose knowledge of the *tithi*. In the Vedāṅga-jyotiṣa period, about 1400 years before Śaka, tithi and nakṣatra or sāvana day and nakṣatra were the only two factors used. The tithi lasts for about 60 ghaṭis; in a way it represents the day and night together. Similarly, the factor known as 'karaṇa' which represents simply a day or a night and which is equivalent to a half-tithi may have come into use very soon after the tithi, and the days of the week (the vāras) may have followed later. The Karaṇa and Vāra have both been mentioned in the Atharva Veda. It has been shown before (pages 138 & 139 of Part I) that Meṣa and other names became current in our country 500 years before Śaka. It has also been mentioned before (page 106 of Part I) from the evidence obtained from the Atharva Jyotiṣa and the Yājñavalkya Smṛti that the days of the week came into use some centuries before the 'Rāśis' (signs). The sunrise is supported by another work. In the appendix to the Ṛk-Gṛhya Sūtra

only the days of the week, and not the Rāśis, have been mentioned along with the tithi, karaṇa, muhūrta, nakṣatras, Nanda and other names of tithis, and dinakṣaya (*i.e.* suppression of a tithi). All these three works were compiled before Meṣa and other names came into use and it cannot be that they were all compiled at one time. This shows that the days of the week came into use at least some centuries before Meṣa and other terms. The *Vāras* and the terms Meṣa etc., might have originated at any place, but they could not have taken a very long time to spread, for there are no intricacies of calculation in them. From this it appears that the days of the week and the terms Meṣa etc. did not come into use in our country simultaneously, irrespective of the place where they originated. The days of the week may have been introduced in our country about 500 years before Meṣa and other terms came into use, as mentioned before, that is, about 1000 B.S. (before Śaka). They are at least not more modern than 400 B.S.*

The time-unit of 'karaṇa' would easily be suggested by the 'tithi'. Hence, it must have come into use, soon after the tithi, but before the days of the week. Of the works belonging to the Vedāṅga period which have been considered, only three, the Atharva Jyotiṣa, Yājñavalkya smṛti, and Ṛk-gṛhya-pariśiṣṭa, mention the days of the week and only the Yājñavalkya Smṛti fails to mention the *karaṇas*, while the other two do mention them. This shows that the 'karaṇas' may not have come into use before the days of the week. If it be a fact, both of them may probably have come into use simultaneously, or the karaṇas might have followed shortly after the days of the week. They are not more modern than 400 B.S.**

The principle underlying the order of the names of the Vāras, *viz*. Saturday, Sunday, Monday etc. has been already explained on (page. 138 of Part I). It shows that the time-unit called 'Horā' was responsible for it. Another principle that can account for the order of the names is that, if the lordship for ghaṭikās be given to moon and other planets in their ascending order then, starting with the moon as the lord of the 1st ghaṭi on the first day, Mars would be lord of the 1st ghaṭi on the next day, which means that the planet 5th from the Moon becomes the lord of the next day. The rule cited by Varāha,

ऊर्ध्वक्रमेण दिनपाश्च पंचमा: ॥ ४० ॥ . ९०७

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in his Pañca-siddhāntikā, Trailokyasaṃsthāna, lends support to the suggestion that the lord of the day is the fifth planet (in ascending order). But no one hae advanced the idea of the lords of ghaṭikās just as Varāha and others have mentioned the lords of *horās* ; in other words, no one has sought to explain the order of the lords of days and the origin of the days of the week on the basis

*The most modern date that can be assigned to the compilation of the Romaka Siddhāntā would not be later than the beginning of the Śaka era. The Romaka Siddhānta was preceded by the Sūrya and the three other Siddhāntas, and these by the Jyotiṣa Saṃhitā and the Saṃhitā by Meṣādi names.

Hence, the most modern date for the introduction of the *Meṣādi* terms cannot be earlier than 300 B.S. The days of the week would then be antedated by at least a century.

**The *Mahābhārata* does not mention Meṣa & other terms. Nor does it mention the days of the week and the karaṇas which were introduced earlier. Hence, the latest possible date that can be assigned to the *Mahābhārata* cannot be later than 400 B.S. The dates of the Ṛk-gṛhya-pariśiṣṭa, Atharva Jyotiṣa and Yājñavalkya Smṛti cannot be later than 300 B. S.

of the lords of ghaṭikās. Moreover, according to this assumption Monday becomes the 1st day of the week. But nowhere is Monday mentioned as the first day. It appears from this that the names of the days of the week must have originated from the time-unit called *horā* ; and neither the time unit nor the name 'horā' originally belonged to us.

The origin of the days of the week, associated as it is with the idea of 'horā', has a bearing on something much more important than that. It has already been shown before, that the lords of horās are planets taken in the order, Saturn, Jupiter, Mars etc. Hence, he who determined the lords of the horās definitely knew the order of the planets' orbits round the earth, *viz.* the Moon, Mercury, Venus, etc. which is a proof that they had considerable knowledge of the planetary motions. This is a very important fact in the history of ancient astronomy. Our works on astronomy mention the revolutions of planets in the order, Sun, Moon, Mars, etc. that is, in the order of the names of days, and not in the order Moon, Mercury, Venus, etc. If people had attained the knowledge of the order of planets according to their motions, before the days of the week came into use, the motions would have been mentioned in the order of Moon, Mercury, Venus, etc. and not as Sun, Moon and Mars. The fact that they are so given leads one to infer that the adoption of this order was due to the sense of importance or reverence inspired by the order of the names of days before the order of planets according to their motions was known. Another point is that the works on Jyotiṣa Saṃhitā describe in the Chapter on Graha Cāra (*i.e.* the courses of planets) the planets in the very order of the Sun, Moon, Mars, etc. Some Saṃhitā works, at any rate, are more ancient than the Sūrya Siddhānta and other works, and they do not exhibit such knowledge of planetary motions as would be sufficient for the creation of the scheme of the days of the week. These two facts, coupled with the exotic nature of the *horā* as a time unit, go to prove that the seven-day week is not an indigenous institution.

The foregoing explanation implies that even if our people independently attained the knowledge of the order of planets according to their motions this knowledge had already been attained by foreign astronomers.

The days of the week are only seven, wherever they are used on the earth and their order is everywhere the same. It shows that the scheme of the week must have originated at some common source. Some European scholars give the credit for it to Egypt, while others give it to Chaldea. Cunningham* writes, "Dio Cassius (200 A.D.) says that the system of the seven-day week belongs to Egypt. But the Egyptians did not divide a month into weeks of 7 days each but into parts of 10 days each". It can be said, therefore, that the seven-day week did not originate in Egypt ; but the Egyptologist named Renouf, who is proficient in deciphering the script of that country and in the ancient languages, writes** in his book in 1890 that the horās or horus were deities ruling day and night in Egypt. It appears from this that the word 'horā' and the time unit denoted by it, was no doubt in common use in ancient Egypt. There is, therefore, the possibility of the week having originated there. The word 'horā' is now-a-days supposed to be Greek in origin. But Herodotus (5th century B.C.) writes that in fact, the time unit was received by the

*Indian Antiquary, XIV, P. 1—4.

**See this author's book entitled *Dharma Mīmāṃsā*, "Bhautika Dharma", p. 127.

Greeks from the people of Babylon that is from the Chaldeans. It is not known if either of the two nations, Egypt and Chaldea, knew the order of planets according to their motions, and if so, which of them and who received it first. Hence, it cannot be said for certain where the seven-day week originated. They might have originated even in Greece. But they did not originate in any country other than these three.

Regarding the use of the names of the seven days of the week in other countries, Cunningham writes*, "Tibulus (a Roman) refers to a Saturday in 20 B.C. Similarly, Julius *Fantinus* (from 70 to 80 A.D.) remarks that Jerusalem was captured on a Saturday. It appears from this that the Romans had accepted the system of the week about the beginning of the Christian era. But the Persians and the Hindus knew the scheme of the week at about the same period or even before it. Selusus lived during the reign of Augustus (27 B.C.) and Tiberius. He observes that the temples in Persia had seven doors named after the seven planets and the doors used to be made of those metals and colours which were loved by the planets**.

Several copper plate and stone inscriptions have been found in our country and the earliest instance in which the day of the week has been mentioned belongs to Śaka 406. There is a stone pillar at Eron in Central Province which bears an inscription of King Budhagupta ; it refers to Thursday, the 12th lunar day of the bright half of Āṣāḍha in Gupta year 165 *i.e.* Śaka 406. No astronomical 'human' work is at present available which states, in clear terms, a period before this as the date of its compilation.

WHEN 'YOGAS' CAME INTO EXISTENCE ?

Keropant Nānā observes that it is not known what planetary position in the sky is indicated by the 'Karaṇa' and that it is useful only in astrology. But*** it is not the correct view. The Karaṇa is equal to a half tithi. Just as a tithi shows that the Moon has gone ahead of the Sun by 12 degrees, the Karaṇa indicates an increase of 6 degrees in the elongation. In addition to this, as the Karaṇa lasts for about 30 ghaṭis, it is a reasonable time unit. What has been said by Keropant Nānā about the Karaṇas really holds good in regard to Viṣkambha and other 26 Yogas. A man is 20 miles away from Poona and another man is 40 miles away. The sum of the two figures comes to 60 miles. But this figure of 60 miles does not help us in finding the position of either of them; and it is my belief that the *Yoga* entered the Pañcāṅga calculation several centuries after the other factors. The Pañcasiddhāntikā gives the methods of calculating the tithi and the nakṣatra, but it does not give one for finding the Yoga. Similarly, the *Bṛhatsaṃhitā* has considered at length the effects of nakṣatras, but not those of the Yogas. I think, therefore, that the Yogas did not exist at the time of Varāha Mihira. Āryabhaṭa has not given any method for calculating the tithis and nakṣatras, and hence nothing can be said about Yogas in his time. Brahmagupta has explained the method of calculating tithis and nakṣatras, and he has added there a couplet to explain the calculation of the Yoga. But the couplet occupies a position

* Indian Antiquary, Vol. XIV, p. 1-4.

** Our ancient works also mention the metals like gold and the colours which are liked by different planets. It is well known that some people wear turbans of seven different colours on the seven days of the week.

***Planetary Tables, p..163.

between the 62nd and 63rd couplets in the author's copy of the work which has been made from the manuscript in the Deccan College collection. Even if it is left out, the remaining couplets would be in their proper order, because this couplet is unnumbered. Brahmagupta has remarked in the end of the second chapter in which it is found to-day, that the chapter contains 67 couplets. But if the couplet concerning yoga be included the total number would be 68. Another point is that the couplet has no commentary by Pṛthūdaka and the edition with the commentary of Pṛthūdaka does not even contain even the bare couplet. In addition, it is to be noted that, while Brahmagupta has the terms tithi-nakṣatra-karaṇa, in a group, at several places, nowhere does he include the word yoga in it. The references are as follows :—

संक्रांतिभतिथिकरणव्यतिपाताद्यंतगणितानि ।। ६६ ।।

ज्यापरिधिस्पष्टीकरणदिनगतिचरार्धभतिथिकरणेषु ।। ६७ ।।

अध्याय. २

संक्रांतेराद्यंतौ ग्रहस्य यो राशिभतिथिकरणांतान् ।।

व्यतिपाताद्यंतौ वा यौ वेत्ति स्फुटगतिज्ञ: स: ।। ६ ।।

एवं नक्षत्रांतात्तिथिकरणांताच्छशिप्रमाणाद्गतात् ।। ३१ ।।

अध्याय १४

Although the Brahmasiddhānta thus refers to nakṣatra-tithi-karaṇa, in one group, at four places, but the word *yoga* is included nowhere. The *Khaṇḍakhādya* as extant at present gives a couplet describing the method of calculating the yogas, but that too is an interpolation like the above one. Albiruṇī has mentioned a number of things from the Khaṇḍakhādya, but has not mentioned any yogas*. He observes that the *Karaṇatilaka* gives 27 yogas. Had Khaṇḍakhādya given a method of calculating yogas, Albiruṇī would not have failed to refer to the Khaṇḍakhādya in respect of the yogas. It, therefore, follows that the yogas did not exist at the time of Albiruṇī.

There are instructions in the Atharva Jyotiṣa as regards the rites to be performed on particular muhūrta, tithi and karaṇa. But it does not mention any rites to be performed on any yogas ; and later on it is observed,

चतुर्भि: कारयेत्कर्म सिद्धिहेतोर्विचक्षण: ।।

तिथिनक्षत्रकरणमुहुर्तनेति नित्यश: ।।

This directs one to perform auspicious rites on certain tithis, nakṣatras, karaṇas, and muhūrtas ; but no *yogas* are mentioned. But the word yoga occurs in later verses ;

तिथिरेकगुणा प्रोक्ता नक्षत्रं च चतुर्गुणं ।।

वारश्चाष्टगुण: प्रोक्त: करणं षोडशान्वितं ।। ६० ।।

द्वात्रिंशदगुणो योगस्तारा षष्टिसमन्विता ।।

चंद्र: शतगुण: प्रोक्त: ।। ६१ ।।

But astrological works describe 28 yogas ; depending on contributions of the nakṣatras and the days of the week, and the word *yoga* in the above verse might have been used in the same sense ; or else the verse may be an interpolation. The Ṛk-gṛhya-pariśiṣṭa does not mention the yogas.

*India, Part II, p. 209.

Lalla's Dhīvṛddhidatantra does mention the yogas. But the passages may be spurious or else the yogas might have come into common use very recently in those days in his province. The author therefore, feels convinced that the yogas did not form an integral part of the Pañcāṅga till Śaka 600. In the couplets of Brahmagupta cited above, the word *vyātipāta* occurs twice ; but it is not one of the 27 yogas. It is one of the two mahāpātas, which occur when the Sun and Moon are parallel in declination. There is no doubt about this as can be seen from the context and commentaries. There is a crude method of finding the parallel in declination which is made use of even in worksón astronomy ; according to isthmethod, the parallel occurs when the sum of the longitudes of the Sun and Moon is 6 signs or 12 signs, the first parallel being called Vyātipāta and the second Vaidhṛti. In order to find this parallel it is required to find the *yoga* or sum of the longitudes of the Sun and Moon. This must have led to the idea of finding yogas by the sum of longitudes just as the tithi is determined by the difference of longitudes.

SHORTER NAKṢATRA DIVISIONS

The generally accepted length of the nakṣatra division is the 27th part of the Ecliptic or 800 minutes. But there was a syst em according to which some nakṣatras had half the usual length, some had the usual length and the rest had half as much more. Brahmagupta and Bhāskarācārya have referred to it as a system mentioned by Garga and others for astrological purposes. According to this system, the six nakṣatras, Bharaṇī, Ārdrā, Āśleṣā, Svātī, Jyeṣṭhā and Satabhiṣak had half the normal length ; Rohiṇī, Punarvasū, the three Uttarās and Viśākhā—these six had $1\frac{1}{2}$ length, and the remaining 15 had the normal length.

Garga and Brahmasiddhānta methods

Garga had adcpted 800 minutes of arc as the measure (for a uakṣatra) while Brahmagupta adopts 790′ 35″ which is the mean motion of the Moon ; and following these assumptions, the Brahma Siddhānta system has given 4° 14′ 15″ as the extent of the Abhijit nakṣatra, which is found thus : [minutes of 360°—(27×790′ 35″)]=4° 14′ 15″. According to this system, Nārada has given the time measures of nakṣatras thus : 15 muhūrtas (or 30 ghaṭikās) for half-length nakṣatras, 30 muhūrtas, for full length ones, and 45 muhūrtas for those $1\frac{1}{2}$ times long ; and they are correct when mean motion is adopted. This system appears to have been in actual use for some years. An inscription of Bhojadeva, king of Kanauj, has been found at Devagarh, a place about 60 miles to the S.W. of Jhānsi ; which contains the following words : "On Thursday, the fourteenth lunar day of the bright half of Āśvina, on Uttarā-Bhādrapāda nakṣatra, in Samvat 919-which is equivalent to Śaka 784." The nakṣatra is found to be correct only by the Garga or Brahmasiddhānta system ; and not by the usual* system of taking a nakṣatra asan arc of 800 minutes. Now-a-days, it is considered whether the diurnal nakṣatra, on which the Aries Ingress takes place, has the time measure of 15,30 or 45 muhūrtas, in order to decide whether it portends abundance or famine ; and the method has its origin in this very system. Further, it is also clear that the fact that the junction stars of nakṣatras are not situated at equal distances, may have led people to assume unequal arcs for the nakṣatra divisions.

The question of the beginning of nakṣatra cycle has already been dealt with (page 266).

*The author had given a detailed calculation of this in the Indian Antiquary, January 1888, page 24 and a detailed description of the system would be found in his article "Twelve-year Cycle of Jupiter" in the same issue.

ALMANACS IN USE IN DIFFERENT PROVINCES

Let us now see what kinds of almanac are in use in different parts of this country. The author has seen most of the almanacs current in the different provinces and has got them in his collection. On consulting these almanacs one may safely conclude in a general way that the same kind of almanac is current in all the provinces. They differ from one another to some extent in respect of the timings of tithi, nakṣatra, yoga and karaṇa and this variation is due to the fact that the almanacs in use in different provinces follow the works of three schools : **the Saura, the Ārya and the Brāhma Pakṣas.**

THREE SCHOOLS

Some information about the three schools, has already been given (page110) The *Grahalāghava* (Śaka 1442) refers in clear terms to these three schools. Gaṇeśa Daivajña stated how a planet's position stands the test of observation if computed according to a certain school and actually adopted the positions accordingly in his works. He held that the *Sūrya Siddhānta, Karaṇa Prakāśa and Karaṇa Kutūhala represented respectively the Saura, The Ārya and the Brāhma Pakṣa* (page 133). The Karaṇa Kutūhala was preceded by the Rājamṛgāṅka which was similar to it in all respects. These three schools are clearly seen in the Muhūrta work entitled *Muhūrta Mārtaṇḍa* (Śaka 1493). Similarly, Viśvanāthī and other commentaries refer to them at places. Astronomers who swear by one of the three schools are found even in the present times. The Vaiṣṇavas regard the Āryapakṣa as acceptable. According to Sudhākara Dwivedī, the following statements (in favour of the Ārya school) are met with in the "Kṛṣṇāmṛta vākyārtha," a work of the Mādhava sect :—

विष्णोश्च जन्मदिवसाश्च हरेर्दिनं च विष्णुव्रतानि विविधानि भं विष्णुमं च ।
कार्याणि चार्यभटशास्त्रत एव सर्वैः ।

and also "आर्यभटसिद्धांतसंमतकरणप्रकाशग्रंथः"

Some stray sentences bearing a similar import were found in a Dharmaśāstra work entitled, *Smṛtyārthasāgara*. It appears that at the time of Gaṇeśa Daivajña school-spirit ran high and therefore, he employed the ruse of declaring that he had taken a particular planet's place from a particular school, in order to please all the schools of his day. He could, otherwise, have taken them from some single work, adding necessary correction by means of some such remark as Āryaḥ seṣubhāgaḥ śaniḥ (that he had taken Saturn's place with an addition of five degrees, from the Ārya-Siddhānta) or by adopting some other mode of correction. The *Rājamṛgāṅka* belongs to Śaka 964. The corrections devised by Lalla belong to a period 300 years earlier (The *Karaṇa-prakāśa* was compiled after applying them to the Āryasiddhānta). The importance of the modern Sūrya-Siddhānta must have come to be felt even in the times of Lalla. These schools, therefore, are very ancient. But with the advent of the Rājamṛgāṅka*, their differences may have become more emphatic and given rise to a special attachment to one's school. If one habitually makes his calculations from a particular work, his descendants and disciples are bound to follow suit ; and it is but natural that they should begin to feel pride for the school to which the work belongs. It appears

*An earlier work of equal value has not yet come to my notice, if extant at all.

that even a feeling of hatred may have been engendered among the followers of the three schools in certain cases. Really speaking the difference between these schools lies in the fact that the moments of solar ingresses and planets' ingresses differ by some ghaṭis owing to the difference in the year-lengths and the moments of planentary ingresses into signs vary by some days according to the rapid or slow motions of planets because of the difference in planetary motions ; and it has been pointed out before, in our study of the Siddhāntas, that these schools receive only a nominal support from the siddhānta works by which they swear, for everytime an astronomer-observer noticed any variation in the positions of planets as found by calculation, he devised some suitable corrections for basic original work. Hence, it is futile to entertain a false sense of pride in respect of any school.

ALMANAC : ITS CALCULATION AND CIRCULATION

The **oldest almanac** printed and published in this province Mahārāṣtra that has come to the author's notice belongs to **Śaka 1753**. It appears therefore, that almanacs began to be published in *Mahārāṣṭra* about that period. The almanacs which are printed in Bombay and Poona in the Marāṭhī (Bālabodha) script, are all based on the Grahalāghava and the Laghu Cintāmaṇi. The ending moments of tithi, yoga and nakṣatra, in ghaṭis are found from the Laghu Cintāmaṇi and the remaining calculation is done from the Grahalāghava. *In Konkan*, the Bṛhat Cintāmaṇi is used more often than the Laghu Cintāmaṇi. The timing of *tithis*, etc. as found from that work are slightly more accurate. The almanacs of Bombay and Poona adopt 4 as the 'palabhā' and 40 yojanas West as the 'deśāntara' (longitude). For several years the calculation for the almanacs printed in most of the printing presses used to be done by Ābā Jośī Moghe of Bassein. From Śaka 1798, his son Pāndurang Āba used to do the work. Since Śaka 1818, his son Rāmacandra Pāndurang has been doing it. For several years past the almanac of the Nirṇaya Sāgar Press is being compiled by Cintāmaṇi Purūṣottam Purandare Jośī of Bassein. This almanac and the one compiled by Moghe and printed at Gaṇpat Kṛṣṇājī's Press contain figures only a little more accurate than those of other almanacs. In reality, however, all almanacs published in Bombay and Poona are identical, and they are current practically throughout Mahārāṣṭra. A number of booksellers told me that these almanacs are used by the Marāṭhī-speaking people in the Hyderabad State and also in border areas of Telangana and Kanarese territories. Sometimes almanacs are published at principal towns of some districts in Mahārāṣṭra, which are also based on the *Grahalāghava*. Even those printed at Belgaum and Dharwar and in use in the adjoining territories, are compiled from the *Grahalāghava*. Again the Grahalāghava almanac is used in the Vijapur and Karwar districts. It is in common use in the Bellari district of the Madras Presidency. The same almanac seems to be in use even in other Kanarese districts of that Presidency. Only the *Grahalāghava* almanac is in use in the province of *Berar* and at *Nagpur*. Again, the almanacs which are at present published by the Governments of *Indore and Gwalior* States or under their patronage and which are used by almost all the people in those States are compiled from the Grahalāghava. It appears from this that almanacs prepared from the Grahalāghava must be in general use in those areas where the Deccanis predominate or are in majority. The author has in his collection an almanac, printed at the Akhabāre Saudāgar Press in Gujerati characters and in the Gujerati and Sanskrit languages. It has strong resemblance with the *Marāṭhī almanacs* published in Bombay.

It seems that all almanacs printed in Bombay and in use there and among the Gujerati-speaking people elsewhere must be similar to this one. One of the author's friends wrote to him from Navsari "No almanacs other than those published in Bombay are used here. The Bombay almanacs are in use also in areas around Surat". A friend from Kathiawaḍ writes, "Almanacs compiled in Marāṭhī and Gujerati and published in Bombay are used in these parts. Those published at Ahmedabad are also in use." This friend sent me an almanac for Śaka 1810, printed in Bālabodha characters, in Gujerati and Sanskrit languages, and printed at the Union Printing Press, Ahmedabad. The positions of planets in it are calculated entirely from the Grahalāghava. The tithis and other parts also are probably prepared from the Tithi Cintāmaṇi. The Baroda State uses only the Grahalāghava almanac. One may safely conclude from this that almost the entire province of *Gujerat* uses the Grahalāghava almanac. Formerly in all big cities the local astronomers used to prepare their own almanacs ; even to-day we come across some such instances. But as printed almanacs are now available at a moderate price, the manuscript almanacs have vanished. When formerly different astronomers used to compile almanacs themselves, it appears that some of them in *Mahārāṣṭra and Gujarat* may have been almanacs of the **Brāhma and the Ārya schools** ; and we do come across references to this effect. Viśwanātha in his commentary on a Tājaka work remarks that in preparing an annual reading the sun's place should be calculated according to the school that was followed in casting the radical horoscope. The author of the *Muhūrta Mārtaṇḍa* (Śaka 1493) was a resident of a place near Devagad (Daulatabad). He has given in that work an example of a suppressed month in which he gives the calculation of the solar ingress and tithi, both according to the *Brāhmapakṣa and Āryapakṣa.* It appears from this that almanacs belonging to the two schools and used to come to his notice in his province. Navasari friend writes that the local Jośīs prepare almanacs from the *Brahma-māna-sāraṇī*, but do not print them. Other evidence also goes to reveal that the Brahmapakṣa must be very predominant in Gujerat. That Jośī almanac-makers are becoming extinct day by day on account of printed almanacs is indeed a serious loss ; but it is counterbalanced by a gain in another direction inasmuch as uniform almanacs are everywhere come into common use.

An almanac known as *Caṇḍu Pañcāṅga* is in use among the Marwari people. It is compiled for the longitude of Jodhpur, the palabhā assumed being 6. There are a few almanacs of this kind printed in Bombay. The sun's place and the solar ingresses in it show that the compilers follow the Brahmapakṣa ; and the ahargaṇa which they give, is calculated according to the Karaṇakutūhala. But they also give shorter ahargaṇa. The planetary places do not agree with those calculated from the Karaṇakutūhala, and the tithi and other factors, also show a little variation. This shows that another work must have been compiled by applying corrections to the Karaṇākutūhala and they appear to be compiling the Caṇḍu almanac on the basis of the new work.

The *Makaranda* holds the field at Vārānasī, Gwalior and many regions in Northern India, and the almanacs based on that work are current among the people of those regions. (page 127).

The author had with him a *Siddhānta Pañcāṅga* for Śaka 1809, which is printed in the *Telugu characters* in Madras. It is prepared by adopting $3\frac{1}{2}$ as the palabhā. This and the facts stated earlier, (page 260) clearly show

that it is in use in the province of Telangana to the north of Madras. The moments of Sun's ingresses given in it show that it has computed the sun's place from the Sūrya-Siddhānta. But the positions of other planets do not tally with those of Graha Lāghava or *Makaranda almanacs.* It is not yet known from what work they are calculated. They may have been calculated after applying some other corrections to the Sūrya Siddhānta.

Some almanacs printed in the *Malayalam characters* were available at Cochin. It gives the moment of Meṣa ingress in Śaka 1809 as 8gh. 57 pal. on Tuesday, the 5th lunar day of the dark half of 'amānta' Caitra.

The moments are given below of true Meṣa (Aries) Ingress as calculated from different works to show how far the three schools differ in timing the solar ingresses :—

Moment in ghaṭi-palas after mean sunrise at Ujjayinī on Tuesday, the 5th lunar day of the dark half of 'amānta' Caitra, Śaka 1809 (12th April, 1887),

	gh.	pal.	
Original Sūrya Siddhānta	13	18	
Modern ,, ,,	15	14	Saurapakṣa
First Ārya Siddhānta Karaṇaprakāśa	7	31	Āryapakṣa
Second Ārya Siddhānta	10	25	
Rājamṛgāṅka, Karaṇakutūhala	10	45	Brāhmapakṣa.

As calculated from the Brahmasiddhānta, this ingress takes place at 54gh. 46p on Sunday, the third lunar day of the dark half of Caitra, that is, about 2¼ days earlier. But it has already been pointed out before that the Brahma-siddhānta had gone out of actual use from about Śaka 964. The moment of ingress, 8gh-57pl, given by the above-mentioned Malayalam almanac very nearly agrees with that of the first Āryasiddhānta. The difference of 1gh-26p is due to such factors as longitude, ascensional difference, etc. It is evident from this that the almanac follows the Āryapakṣa. The positions of some of the other planets given by it agree with the positions calculated from the Karaṇaprakāśa*. With regard to those which do not agree, the difference is perhaps due to some different mode of corrections employed. From other evidence also it can be seen that the Āryapakṣa is followed in those provinces of the Madras Presidency which speak Malayalam and Tamil languages. It is learnt that the local almanacs are prepared from a work named 'Vākya-karaṇa'. I have not seen the work ; but there is not doubt that the almanacs are compiled with the help of that work or from some other work following the Āryasiddhānta.

The author got an almanac published in *Calcutta*. It cannot be clearly ascertained what work has been followed in it, but it has adopted the year length given by the *Sūrya Siddhānta*. From this it appears that that the *Sūrya Siddhānta year-length is followed in Bengal.*

*Although the author was not quite at home in the Telugu and Malayalam script, he gathered the above information from both the almanacs after reading them with great effort, and he was pretty sure that it is quite correct.

The work Pañcāṅga Kautuk (page 167) shows that in Kashmir, almanacs used to follow the *Khaṇḍakhādya*, for a good many years, that is to say up to about Śaka 1580, and they may still be doing so. The *Khaṇḍakhādya* should not, however, be regarded as being preserved uptil now in its original form. The commentaries show that several kinds of corrections have been applied to it. The moments of ingresses calculated from the Khaṇḍakhādya happen to agree with that by the original Sūrya Siddhānta and are nearer to those of the modern Sūrya Siddhānta than other works.

IMPORTANCE OF WORKS

All things considered, one may say that the *Grahalāghava* and the *Tithi Cintāmaṇi* are the most extensively in use. *Makaranda* stands next place in respect of circulation. These three works have adopted the year-length of the modern S.S. The same length of the year is used in Bengal and Telangana. In other words, this measure is used by five-sixths (5/6) of the population of this country. In Marwar, the year-length of the Brāhmapakṣa is in use while that of the Āryapakṣa has been favoured in the Dravidian and the Malabar provinces. That of the original S.S. is in use in Kashmir. Before printed almanacs came into use, astronomers in all the leading cities used to compile their own almanacs. In those days, almanacs belonging to different Schools may, in certain cases, have been prepared by some; but the details described above must have been mainly followed everywhere. They are being definitely followed at the present time. I have already described in detail in the chapter on mean motions, what Siddhānta works, Karaṇa works and Sāriṇī works (on tables) had influence over the almanac-makers' business during the Jyotiṣa-Siddhānta period, together with the extent and period of their influence.

Verifiable new almanacs

None of the Nirayaṇa almanacs current at the present time can stand the test of observation. So some very precise almanacs are being published now-a-days, which, it is claimed, are verifiable by observation. I propose to describe such almanacs below.

THE KEROPANTĪ OR NEW PAṬAVARDHANĪ ALMANAC

This almanac began to be published since Śaka 1787. It has adopted the latitude and longitude for Bombay for calculation. The late Kero Lakṣmaṇ Chatre was its compiler and the late Ābāsāheb Paṭavardhan was the sponsor of the almanac. For some years in the beginning, Keropant himself appears to have done the whole calculation. Later on, Ābā Jośī Moghe of Bassein, used to do the work under his guidance, and after the former's death, his descendants are doing it. It is learnt that since the death of Keropant his second son Nilkanṭh Vināyak Chatre supervises the calculation work. Another son of Keropant and one of Keropant's pupils are also said to be taking part in the work. Janārdan Hari Āṭhale, proprietor of the Jaganmitra Press at Ratnagiri, takes great pride in this almanac and he used to print it at his own expense from Śaka 1791 to 1811. This almanac was at first known as the "Navīn Pañcāṅga"—(the New Almanac). At first, Ābā Sāheb Paṭavar-

dhan used to bear the expenses of the calculation work and now they are being borne by his descendants. Ābā Sāheb had a great liking for this subject. He had spent about three or four thousand rupees in purchasing some instruments and he used to take observations himself. It is true that the idea of this almanac was originally suggested by Keropant, but it would not have seen the light of the day without the encouragement given by Ābā Sāheb. The almanac came to be called "Navīn or Paṭavardhanī Pañcāṅga" since Śaka 1799, as a tribute to the memory of Paṭavardhan. Since Śaka 1812, Vāsudeva Gaṇeśa Jośī, proprietor of the Citraśālā Press, has been printing this almanac at his own expense. As the sale of the almanac is very limited, the publication is not self-supporting. If Āṭhale and Jośī had not undertaken the responsibility of printing the almanac, it would have become extinct long ago. But no one has ever publicly expressed gratitude for these service, nor even cared to declare the fact that they print it at their own expense.

The Keropant's almanac is different in two ways from the universally used almanacs in our country. The first point of difference is that in this almanac, the equinoctial motion has been taken to be the actual value viz. $50\frac{2}{10}$-seconds of arc, and Śaka 496 as the Zero precession year because in that year the equinox coincided with Zeta-Piscium, the junction star of Revatī ; naturally, therefore, the length of the year adopted is the actual length of the sidereal year viz. 365^{d}-15^{gh}- 22^{p}- 53^{v}. Consequently, the figure for ayanāṃśas for any year should be the distance of the equinox from the junction star of Revatī. The ayanāṃśas in the beginning of Śaka 1808 have been taken to be 18°17′.* The second point of difference is that the positions and motions of planets in this almanac being quite accurate, the phenomena like eclipses, conjunctions of planets, etc., are found to agree with observation**. The almanac is prepared with the help of the *English Nautical Almanac*. Because of this fact and also because the English almanac which is extremely accurate agrees with observed results, Keropant's almanac can naturally claim the same degree of accuracy. These almanacs will be further considered in our study of the question of almanac reform. Keropant has not prepared any Marāṭhī or Sanskrit book which would be helpful in compiling the almanac of this sort. Venkaṭeś Bāpūjī Ketkar has recently compiled such a work (pages 179, 184).

DRIGGAṆITA PAÑCĀṄGA

Raghunāthācārya*** of Madras began its publication from Śaka 1791 (page 182). It is compiled from the Nautical Almanac. It is printed both in *Dravidian and Telugu characters*, which shows that it is very much in demand in those parts. It is called the *śiriya* (short) almanac. It is learnt, that when Raghunāthācārya was alive he used to compile a *periya* (large) edition of the 'drigganitapañcāṅga'. The author got the shorter almanac

*Taking into consideration the position of the star Zeta Piscium, the most accurate calculation shows that the ayanāṃśas, in the beginning of Śaka 1808 ought to be 18°17′10″. Paṭavardhan's almanac is erroneous by 10 seconds.

**The times of heliacal rises and sets of planets sometimes do not tally but this is due to quite a different reason. The question has been considered later on in the chapter on 'Rise and Set'.

***Cintāmaṇi is the surname of Raghunāthācārya. According to Nateś Śāstrī, he was a resident of Kābāṇḍalam, a village situated 8 miles to the East of Kāncī.

for Śaka 1818 (current Kali year 4998) printed in Dravidian characters, which is compiled by Venkaṭācārya, son of Raghunāthācārya. It has given in it the moment of the Nirayaṇa Meṣa ingress in Śaka 1819, as 52 ghaṭis 43 palas on Sunday the 11th April 1897. The true Meṣa ingress calculated from the Sūrya-Siddhānta comes to occur about the samé time. (The difference is very small). It appears from this that it has adopted for its ayanāṃśa at the beginning of the Śaka year 1819, an arc of 22°15′ which is the difference between the sun's longitude as calculated from the Sūrya Siddhānta and the Sāyana place of the sun (at the moment of the Nirayaṇa Ingress), as obtained from the *Nautical Almanac*. It seems that the almanac has adopted the *latitude and longitude of Madras*.

BĀPŪDEVA'S PAÑCĀṄGA

Pandit Bāpūdeva Śāstrī recognizes the importance of the sāyana system. About 1863 A.D. he had delivered a lecture in English on the *scientific character of the sāyana system*, which has been printed. Although he appears to be convinced of the fact that the sāyana-pañcāṅga is scientific, he began to compile from Śaka 1798 a nirayaṇa almanac and publish it under the patronage of the Mahārājā of Vārānasī. In doing this he was apparently prompted by the desire to satisfy those people who follow the nirayaṇa pañcāṅga, for, in the Introduction to the almanac he writes, "I am urged to compile an alman ac under instructions from His Highnessī Śvarīprasād Nārāyaṇa Siṃha Bāhā dur of Kāśī ı............Although it is the sāyana system which is really the superior system, I have prepared this nirayaṇa *tithipatra* (almanac) for the satisfaction of the public, since in India the nirayaṇa system is everywhere followed".

Bāpūdeva's almanac is prepared from the English *Nautical Almanac*. Its calculations are based on the *latitude and longitude of Kāśī*. He observes that the ayanāṃśas adopted are equal to the difference between longitudes of the sun as obtained from the Sūrya-Siddhānta and other works and its accurate sāyana longitude. A comparison of the sāyana place of the sun in the Nautical Almanac and that taken by Bāpūdeva in his almanac shows that he has taken about 22°1′ as the ayanāṃśa for Śaka 1806. This year, the Sun's entry into Meṣa, according to the Sūrya-Siddhānta, takes place, at 30^{gh}-26^{p} after sunrise on the horizon of Kāśī, on Friday, the first lunar day of the dark half of amānta Caitra. Bāpūdeva's almanac has given it as at 31^{gh} -12^{p} on the same day. This moment is in advance of the Sūrya Siddhānta by 46 palas, but it does not agree with the figures obtained from any other Siddhānta ; it is evident that he has taken the sun's place according to the Sūrya-Siddhānta and not used according to any other Siddhānta. The difference of 46 palas must be an error. When he had a controversy with Keropant, Bāpūdeva stated in the columns of the *Jñyān Prākāśa* of Poona, dated 14th June, 1880, that the sun's place should be taken as obtained from the Sūrya-Siddhānta. He has, however, added therein that it should be the mean position. The sāyana position of the sun, as calculated from the Nautical Almanac for the moment of the sun's entry into Meṣa according to the Sūrya-Siddhānta comes to 22° -0′ -31″, and the figure which ought to be taken as ayanāṃśa must be so much. Since Bāpūdeva had adopted 22°-1′-0″ as the ayanāṃśa, it is clear that he has taken the true place of the sun and not the mean place in his almanac. Some disciples of Bāpūdeva have continued the publication of the almanac after him even to this day.

Bāpūdeva's almanac differs from other almanacs only in one respect The positions and motions of *planets* given in the almanac are very accurate and are seen to agree with observation, because it is prepared from the Nautical Almanac. The ayanāṃśas, however, show a little difference ; but in fact it is no difference. The adoption of the difference between the sun's position as calculated from the Sūrya-Siddhānta and that obtained from the Nautical Almanac as the ayanāṃśa, in a way, amounts to the adoption of the year-length of the Sūrya-Siddhānta. We shall revert to this almanac later when we study the question of almanac reform.

OTHER PRECISE PAÑCĀṄGAS OF THE NIRAYAṆA SCHOOL

Two more precise Pañcāṅgas of the nirayaṇa school calculated from the *Nautical Almanac* have come to the notice. Both of them have been prepared on the nirayaṇa basis. Sundareśvar Śrautī and Venkaṭeśvar Dīkṣit from Tiruvadi in the Tanjore district, have been publishing accurate solar almanacs since Śaka 1798 in *Tamil characters*. The almanac for Śaka 1815 has given 22°10′ as the ayanāṃśa which is almost equal to those adopted by Raghuṇāthācārya for the beginning of Śaka 1815. In that year, the sun's entry into Meṣa takes place at 51^{gh}-31^{p} on Tuesday. An association known as *Jyotistantrasabhā* appears to have started in Tiruvadi. Its Chairman Cidambaram Iyer, has written a small book entitled HINDU ZODIAC. He observes in it that this almanac is published at Kumbhakoṇa under *orders of the Śaṃkarācārya.*

An almanac named *Ajit Prakāśa* prepared for Śaka 1818, by astronomer Rūrmalla, under orders of Ajit Siṃha, Chief of Khetadi State in Rajputana has come to my notice. It appears to have been published for the first time this year. It has adopted 22°11′ as the ayanāṃśa at the beginning of the year. It has been prepared from the Nautical Alamanac, and the *latitude and longitude of Khetadi* have been adopted for calculation. The latitude has been mentioned as 28° and the longitude in time has been given to be 3 pals west of Ujjayinī.

THE SĀYANA PAÑCĀṄGA

The sun actually begins to turn northward or southward on the very days, on which, as shown in all the almanacs current in this country, the length of the day begins to increase or decrease ; and the same thing is actually observed in the sky. Any thoughtful layman would naturally wonder why the almanacs do not mention the phenomenon of this change of course as occurring on those very days, and why the Makar and Karka Saṃkrāntis shown as occurring about 22 days later. The sāyana pañcāṅga which is published these days owes its origin to such enquiring spirit and the investigation that followed it. THE THREE, *Lele, Janārdan Bālājī Modak and the author*, are the originators of the almanac. The idea of publishing the sāyana almanac struck each of them independently. But it was Visājī Raghunāth Lele who really blazed the trail. When Keropant Chatre, started making improvements in the almanac and began to publish an almanac with the help of Ābā Sāheb Paṭavardhan, Lele thought that a complete and thorough reform of the almanac was more desirable than half-hearted piecemeal improvements, and that Keropant Nānā was equal to the task. Lele then launched a campaign of criticism against Keropant's almanac in 1872 (Śaka 1794) through the columns of the *Indu Prakāśa*. In the beginning he got a letter published

in that paper in the name of one Govindrão Sakhārām and suggested *inter-alia* that the tropical year should be adopted, if any reform of the almanac was to be carried out. Keropant retorted : "I am not the only follower of the nirayaṇa almanac. There are, people, from one end of the country to the other, who follow it. Let any one of them deal with your objections, and if no one does so, I will join with you". For several years' however, Keropant did not reply. Lele was all the time pursuing the subject through the press under the pen-name "Sphuṭavaktā Abhiyogi" (Candid Combatant). He still hoped that either Keropant, or Bāpūdeva who expressed merely lip sympathy for the Sāyana system, would start publishing the sāyana almanac and it was his heart-felt desire that either of them should receive the credit for such achievement. But Bāpūdeva started the nirayaṇa pañcāṅga. About 1880 A. D. when Keropant and Bāpūdeva were engaged in a controversy in the columns of the *Jñyān Prakāsa*, on the question of year-length and ayanāṃśa, Lele appealed to both of them to adopt the sāyana system but it was of no avail. Keropant observed in reply to Lele that though the sāyana system was correct so far as the seasons were concerned, he did not ap rove of the idea of compiling the almanac according to that system. And in the course of this reply Keropant blurted out certain views bordering on defiance of *Dharmāśastra* though in his "Introduction" to the Paṭavardhani almanac he used to declare that the almanac aimed at enabling people to perform religious functions at the time prescribed by Dhdrmaśāstra. Lele, therefore, gave up the controversy. At about the same time, as also later on, Lele, Modaka and the author wrote a number of articles on the sāyana almanac in the '*Arunodaya*' news paper of Thānā. As the editor of the paper supported our cause, the sāyana almanac could appear in the paper in fortnightly instalments in Śaka 1804 and 1805. Later on, the patronage of H. H. Tukojī Rāo. Holkar could be secured through the efforts of Kṛṣnarāo Raghunāth Bhide and the sāyana pañcāṅga could be published in proper form from Śaka 1806, and the publication continued for four years while the monetary help also was received.. His Highness Tukojī Rāo died in Śaka 1808 and the patronage came to an end, and no further help could be secured in the absence of any painstaking person like Bhide in that circle. Still, Lele published the almanac for four years from Śaka 1810, almost at his own expense. Since Śaka 1813, the author has been publishing it in the same way. J. B. Moḍak died by the end of Śaka 1811 and Lele in Śaka 1817. The fortnightly instalments of the almanac for Śaka 1818 are being published by the editor in the issues of the *Arunodaya*. The calculations for the almanac were done by Lele in the first year. Those for Śaka 1805 were done by all the three of the makers. During the next 13 years the author has been mainly responsible for the calculation work and general supervision of the almanac. Unlike Paṭavardhanī almanac, no one pays for the labours of calculation ; not only this, but the printing charges also have to be borne by them, since the circulation of the almanac is very limited.

While His Holiness Śaṃkarācārya of Dwarka, the head of the Śāradā Matha, was in Lashkar, Gwalior, in Śaka 1815, V. R. Lele submitted to him different almanacs, including the Grahalāghava, those by Paṭavardhanī, Bāpūdeva's and the sāyana one, and requested him to give his decision as to which almanac should be regarded as acceptable. Then His Holiness considered the matter from all points of view, published an all-India ordinance recommending the use of the sāyana almanac. The ordinance is as follows :—

।। श्रीशारदांबा विजयतेतराम् ।।

श्री द्वारका
धीशो विजयते
जगदगुरु श्रीमच्छङ्क
राचार्य श्रीशारदामठ
द्वारका संस्थाना
धीश्वर मह ।

श्रीमत्परमहंसपरिव्राजकाचार्यवर्यपदवाक्यप्रमाणपारावारपारणियमनियमासनप्राणायामप्रत्याहारधारणाध्यानसमाध्यष्टांगयोगानुष्ठाननिष्ठतपश्चर्याचरणचक्रवर्त्यनाद्यविच्छिन्नगुरुपरंपराप्राप्तषण्मतस्थापनाचार्यसांख्यत्रयप्रतिपादकवैदिकमार्गप्रवर्तकनिखिलनिगमागमसारहृदयश्रीमत्सुधन्वनः साम्राज्यप्रतिष्ठापनाचार्यश्रीमद्राजाधिराजगुरुभूमंडलाचार्यचातुर्वर्ण्यशिक्षकगोमतीतीरवासश्रीमद्वारकापुरवराधीश्वरपश्चिमाम्नायश्रीमच्छारदापीठाधीश्वरश्रीमत्केशवाश्रमस्वामिदेशिकवरकरकमलसंजातश्रीशारदापीठाधीश्वरश्रीमद्राजराजेश्वरशंकराश्रमस्वामिभिः

शिष्यकोटिप्रविष्टान् निरवद्यवैदिकराद्धांतश्रद्दधानचेतः साम्राज्यसमलंकृतानशेषभरतखंडसदायतनविद्वद्वरान् प्रति प्रत्यग्ब्रह्मैक्यानुसंधाननियतनारायणस्मरणसंसूचिताशिषस्समुछसंतुतराम् जगदगुरूणां महेश्वरापरावतारश्रीमच्छंकरभगवत्पूज्यपादाचार्याणामादिमैकांतिकास्थानद्वारकास्थश्रीमच्छारदापीठगोचरा भक्तिरनवधिकश्रेयोनिदानमिति सार्वजनीनमेतत् । सांप्रतम. भगवत्याः शारदाया लष्करनगरीग्वालियरसंनिहितांत्रीजनपदसमावेशवासर्वविशेषमुपक्रम्याप्रस्थितेर्लष्करप्रस्थात्प्रज्ञापितसायननिरयनभेदभिन्नप्रक्रियातिशयसमास्पदीभूतप्रक्रमभरबुभुत्सापरायत्तस्वांतेन लेलेइत्युपाभिधानविसाजीरघुनाथशर्मणा तन्नगरीनिकेतनेनानुपदमभ्यर्हितामभ्यर्थनामुररीकुर्वाणैर्विगानविशेषपरामृष्टप्रत्ययसंधानैरिदमत्रास्माभिरवधार्यते तथाहि

दर्शनसामान्यस्यावान्तरमहातात्पर्यविशेषानुगृहीतविग्रहवत्तयोपक्रमपरामर्शोपसंहारानानुगम्यापिचरमामेव तयोस्तात्पर्यमहाभूमिमभ्युदितफलाभिधेयप्रसवित्रीमाचक्षाणास्समीयंते तीर्थकाराः

अवान्तरतात्पर्यतिकर्तव्यताप्रयुक्तप्रसक्तिनिर्वहणायान्तरपदार्थपरिशीलनं परिवप्रयत्नातिशयस्यार्थवत्वेऽपि तथात्वमेव तस्यावक्लप्तमवसितं भवत्युपसर्जनमुद्रया किलाशेषश्च.

महातात्पर्यकथासुधात्वविक्रतवस्तुभेदप्रग्रहमेव प्रत्यस्तमितसातिशयविधाविधानमपूर्वतरमनुभावयन्ती प्रतर्पयाती च निरूढार्थप्रधट्टिकामसाधारणीं तां चकास्त्येव सर्वशः सरणिरेषा सर्वास्वपि दर्शनस्थितिषु सत्येव साधारणी प्रतिष्ठापयत्यर्थतत्वमिति वस्तुस्थितिः

प्रकृते हि सायननिरयनतंत्रयोरितरेतरप्रत्यनीकभावभावितयोरप्यन्योन्यस्वरूपविशेष-समर्पणकृते कृताकांक्षयोरस्ति हि वैषम्यं भूयः तच्च परिगणितानेकपदार्थविभागभागपि ज्योतिः-शास्त्रमहातात्पर्यैदम्पर्यविषयीभूतकालावयवयाथात्म्यमनुभावयमानं विहितसमस्तश्रौतस्मार्त-क्रियाकलापनियतकालविभ्रमापनोदनिर्मरमनुकूलीकृताशेषशेषभूतवस्तुव्यवस्थाकमपरामृष्टवि-पर्ययप्रतीतिजननमविपर्यस्ताबाधितासंदिग्धदृक्प्रतीतिपर्याप्तमेव परिसमाप्यते स्वाभावभावित-मर्थंत इन्यादरगोचरं भवत्येव सायनतंत्रगतं तदेतत्.

निरयनतंत्रायत्तं तदिदं यथाभूतक्रियाकलापकालनिर्देशानिवर्तनासमर्थसत्तदुपजीव-कतामेवाविवादमश्रुत इति स एष सायनपक्षः सर्वैरपि श्रीमता विसाजी रघुनाथ शर्मणा समर्थितस्सदसद्विचारणापुरःसरमाद्रियतां महाशयैरशेषवर्णाश्रमिभिरिति स्थितम् । अनादि-सिद्धश्रीमज्जगदगुरुसंस्थानाज्ञापरिपालनैकपरपंराकेषु किमधिकं ब्रह्मक्षत्रादिशिष्यवरेष्विति शिवम्.

श्रीमच्छंकरभगवत्पूज्यपादाचार्याणामवतारशकाब्दाः २३६२ फाल्गुनकृष्णाष्टम्यां ८ स्थिरे संबत् १९४९ शके १८१४ (स्वारी मु० धवलपुरम)

(बार अंक २२९) श्री

Lele himself received a letter (No. 218), which may be summed up thus :— "With regard to your elaborate petition concerning the controversy centring round the sāyana-nirayaṇa almanacs, I have to inform you that on weighing all the evidence, I find that the nirayaṇa almanacs should be taken as extremely doubtful, since they do not give the correct time for performing the rites ordained by Śruti, Smṛtī and Purāṇas. As the sāyana pañcāṅga recommended by you gives the proper times, this Saṃsthān of the Jagadguru, declares that the Sāyana Pañcāṅga should be regarded as a suitable almanac for performing religious rites"————(signed) Śaṅkarācārya, on Saturday, the 2nd lunar day of Phālguna, Samvat 1949, the Avatār Śaka 2362, Camp, Lashkar Gwalior*.

There is a twofold difference between the orthodox almanacs and the sāyana almanacs. The first is that the sāyana almanac adopts a different measure for the year length, and the ayanāṃśas are always zero. The second difference is that being prepared from the *English Nautical Almanac* or the French *Connaissance des Temps* (Knowledge of Time), the positions of planets given in it are always correct and verifiable by observation.

The almanac adopts the *latitude and longitude of Ujjayinī* as the basis of its calculation.

STUDY OF ALMANAC REFORM

The calculations of the popular almanacs, such as the Grahalāghava almanac, do not agree with observation ; hence it is necessary that they should be rectified. Of the almanacs newly introduced during the last 30 years, six very precise almanacs have been desribed ; all of them, except the Sāyana Pañcāṅga, are nirayaṇa but even these do not adopt the same ayanāṃśa figure. The writer being of opinion that instead of adopting the nirayaṇa system the almanacs should follow the sāyana system, he proposes to enter into an analytical discussion of the two systems.

*The originals of both the letters are in the possession of Mr. Lele.

Characteristics

The definitions of the sidereal (nirayaūa) and the trpical (sāyna year have already been given (page xxxii of Part.. I). The siderel year is longer than the tropical year by about 51 palas. But the length of the year adopted by all our astronomical works is greater than that of the tropical year by aboact 60 palas. Some point of the Zodiac must be adopted as the initial point to indicate the places of planets. The initial point of the zodiac, according to our astroromical works, coincided with the vernal equidox in Śaka 444 ; and as the length of the year adopted by our works greater thian that of the tropical year by about 60 palas, the position of the initial point is advancing by about 60 seconds (of arc) every year with respect to the vernal equinoz* The distance between the equinox and the position or the initial point, as obtaieed form our works, is called ayanāṃśa, The phenomenon of the percession of equinox was first known from the shifting of the 'ayanal, point, The displacement cf the ,ayana'-point in degrees is the 'ayanāṃśa'. The same term came to bə applied to the shifting of the equinoctial point. in degrees. If the position of a planet reckoned, by taking the equinox as the initial point lt includes the 'ayanāṃśas' and hence the position is termed 'sāyana' (inc usive of ('ayanāṃś2s' ; and it it is reckoned from the initial point assumed by our astronoffiiual wosks, it is devoid of ayanāṃśas, and hence it is termed 'niryae' (exclusive of ayanāṃśas).

Study of Ayaṇāmśaas

According to the *Grahalāghava*, the ayanāṃśa in Śaka 1809 comes to 22″45″, According to Rāja-Migāṅka and other works following the Brāhma-pakṣa and the Karaṇa Prakāśa following the Āıyapakṣa, it comes to 22°44″. According to Sñrya-Siddhānta it amouts to 20°49″ 12″. The Makaranda almanacs and those current in Bengal appear to be adopting the same amount, Similarly, calculatiors made from sāyana ingresses given in the Telangi almanacs descrised before show that they also adopt this amount of ayanāṃśa, But this amount involves a bigger error than the one involved in adopting 22°44″ or 22°45″. The Tamil and Malayalam territories of the Madras presidency adopt an ayanāṃśa equal to that of the *Grahalāghava*. Similarly the *Pancānga Kautuka* and other works show that, in Kashmiı they adopt the ayanāṃś equal to those adopted by thc *Grahalāghavaa*. The moment of Meṣa-ingress is the beginning of the solar year. Hence, as remarked in the course of our study of ayanāmśa niarayana almanac should adopt that figure an the ayanāmśa which in equal to the true sāyana longitude of the observed sun at the moment of the true Nirayana Mesa-ingress, calculated according to the woık, on which the almanc is based ; and this will make the moments of the solstitial and equincctial positions conform to absservation The moments of solar ingress in to Mesa, obtained for Śaka 1809, according to difierent siddhanta works have been given (page 283) before. The arcs obtained by calcu ating the position of the tropical sun at those momenet from the French Almanac or the English Nautical almanac, represent the ayanāmśas which ought to be adopted so as to be in consonance with the length of the year assumed by different works ; these arcs of ayanāṁśa are given below ;—

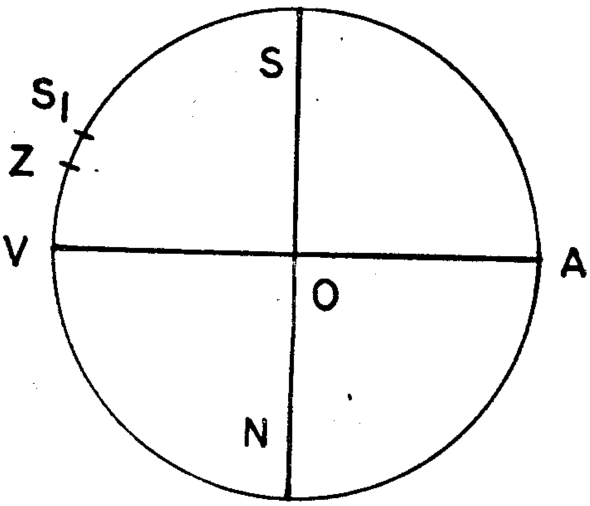
2According to acount calculation made form the length of the year adopted by he Surya Siddhanta it is advancing by 58. The point has been dealt with in detail in our study of 'Ayana Calana.'

If the mean longitude of the sun be taken into account, the ayanamsa for Saka 1809 as obtained from the morden Surya-Siddhanta oould be 22 18 44, and those for others world show a corresponding increase.

	Ayanāṃśa in Śaka 1809		
Original Sūrya-Siddhānta	22°	1′	27.6″
Modern Sūrya-Siddhānta	22	3	21.3
First Ārya-Siddhānta, Karaṇa Prakāśa	21	55	47.8
Second Ārya-Siddhānta	21	58	38.2
Rājamṛgāṅka ; Karaṇa Kutūhala	21	58	57.8

The *Grahvlāghava* has adopted the same length of the year as the Sūrya-Siddhānta and the ayanāṃśa calculated on this basis, come to 22°45′. But they should be 22°3′ as shown above, which means that there is an error of about 42 min. of arc. The sāyana longitude of the sun, as calculated on the basis of (the ayanāṃśas of) the *Grahalāghava*, differs* to that extent from the sāyana sum calculated from the Nautical Almanac.

Bāpūdeva's almanac is compiled from the *Nautical Almanac* ; and it correctly shows the ayanāṃśa for Śaka 1809, to be 'about 22°4'', as calculated above, since he has adopted such a figure for ayanāṃśa as would satisfy the definition of that term given by Bhāskarācārya and others, (Page 218) viz. that "ayanāṃśa is the difference between the tropical longitude of the sun and that obtained from the Sūrya-Siddhānta at the moment of the sun' ingress into Meṣa". Keropant's almanac has given the ayanāṃśa (18° 18′ for Śaka 1809) in accordance with his view that ayanāṃśa is the distance of the vernal equinox from the star Revatī (Zeta Piscium). As for the Sāyana Pañcāṅga the equinox itself being the initial point there is no necessity whatsoever to adopt any ayanāṃśa. The remaining three of the above mentioned six almanacs show nearly 22°3′ as the ayanāṃśa and the figure is no doubt correct.



*It has been been mentioned before (page 213) that during the time-interval between the year-length of the Sūrya-Siddhānta and the length of the tropical year, the tropical sun moves 58″.8 ; and hence 58″.8 or 58″.6 has been recommended for adoption as ayana-motion, this is quite precise. If 58″.7 be assumed as the motion, and reverse calculation be made from the above ayanāṃśa for 1809, the zero-precession year of the Sūrya-Siddhānta would come in Śaka 457. Teh Śaka year 450 found before (page 217) was arrived at by taking into account tne correction due to secular equation and the variationā in the equation of centre.

Definition and nature of the Sāyana and Nirayaṇa Almanacs

The above circle represents the ecliptic. V is the position of the vernal equinox, A that of the autumnal equinox, and Z is the position of the star Zeta Piscium at the present time (about Śaka 1818). Z stands at a distance of about 18°26′ from V. S_1 is the sun's position at the moment of the apparent entry of the Sun into Meṣa according to the Sūrya-Siddhānta and other works. N and S are the winter and summer solstitial points. Point Z is fixed. The equinoctial and solstitial points have got a retrograde motion and it is the same (about 50″ per year) for all these points. As the length of the year adopted by our astronomical works is greater than the actual length of the sideral year by about 8.6 palas, their initial point, viz. point S_1 in the above figure, is not stationary. In other words, point V moves backward with respect to the point Z at the rate of 50 $\frac{2}{10}$ seconds per year while point S_1 moves forward by 8.5 seconds. (page 219).

Taking the vernal equinox as the initial point, the ecliptic is divided into 12 equal parts called 'Sāyana Signs' and again into 27 equal parts, called 'Sāyana Nakṣatras'*. Because the equinox moves, the sāyana signs and nakṣatras also move. When Revatī or any other star is supposed to be at the beginning of the ecliptic, the 12 or 27 equal parts of the ecliptic based on such intial point are called fixed or Nirayaṇa Rāśis and Nakṣatras. The terms 'fixed and moving' are found in our astronomical works. This explanation will enable one to understand the nature and definition of the sāyana and nirayaṇa almanac. Keropant's almanac is compiled on a purely nirayaṇa basis. The year-measure taken for Bāpūdeva's almanac and those compiled from our astronomical works does not agree with the actual length of the sidereal year. But the ayanāṃśa adopted by them are in conformity with the length of the year they have adopted. Hence, the planetary positions shown by them are exclusive of ayanāṃśa and there would be no harm, therefore, if these be regarded as 'nirayaṇa' and the rāśis and nakṣatras in them, as nirayaṇa rāśis and nakṣatras. Similarly, because the length of their year is greater than that of the true sidereal year, their initial point does not remain fixed ; all the same it was the intention of all the Siddhāntas that it should be fixed or stationary, since they have assumed fixed longitudes for stars for all time to come. Hence, the 12 or 27 equal parts measured from the initial point of our Siddhāntas are also fixed rāśis or nakṣatras.

Correct Planetary positions obtainable by any system

The six modernized (accurate) almanacs referred to above differ from those following the old methods in one respect. This difference lies in the fact that three of them give planetary positions agreeing with observation.

*Some people raise the objection that it is improper to apply the attribute 'Sāyana' to such terms as Rāśi, Nakṣatra, month and the pañcāṅga. There has never been any objection to applying the adjective 'Sāyana' to the position of planets ; and Bhāskarācārya and others have applied it accordingly. Then why should there be any objection if the signs and nakṣatra divisions which are formed with respect to sāyana positions of planets, be called sāyana ? Similarly there would be no harm if the almanac, which is compiled according to the sāyana system or related to the sāyana planets be called "sāyana almanac" for the sake of brevity. It is only a technical term. In the course of the debate held at Indore over the question of the sāyana almanac, some quibbler remarked that since the word 'sāyana' is a 'Bahuvrīhi' compound intended to serve as a qualifying or subordinate term, the sāyana Pañcāṅga too is a subordinate matter. The contention, that the term Sāyana Pañcāṅga is incorrect, is equally absurd.

Let us first consider the point. No matter what system the almanac follows, it is expected of it that the times of the occurrence of eclipses, the conjunctions of planets with other planets or stars etc., should be verifiable. If one's calculation goes to show that a particular planet would be seen at a particular place, at a particular time, it must actually appear so when observed through the telescope. Any one will admit that only in that case the almanac would be acceptable. In order that these things should be verifiable by observation, the calculation of the almanac must be absolutely accurate in two respects. Suppose, a man who was at Poona at a particular moment is proceeding to Bombay. If the rate of his speed is correctly known, as so many miles per hour, the time when he will be in Bombay can be correctly calculated and it will be verified by actual experience. Similarly, if the positions of planets at a particular moment and their motions be correctly known, the place where the planet would be found at a particular moment can be correctly predicted and it will prove to be accurate, irrespective of the initial point from where the distance of the planet is reckoned. Suppose that point Z in the above figure (Page 292) is at a distance of 18° from V, point S_1 is at 22° and point S at 90°. On a certain morning a planet was situated at V. It is moving towards S, and is known to be moving at the rate of 1° per day. Then one can say that it will reach S 90 days after it was seen at V, 72 days after it reached Z, and 68 days after it reached S_1 and this will be found to be true. If V be taken to be the initial point and the time when the planet comes there, be regarded as the moment of the beginning of the year, then the planet will be said to have covered a distance of 90° in 90 days after the beginning of the year. Similarly, if Z be supposed to be the initial point it will be taken to have reached a position 72° away in 72 days after the beginning of the year, and if S_1 be the initial point, a distance of 68° in 68 days from the beginning of the year. In other words although its positions and the times of reaching them may appear to be different relatively, they are, as a matter of fact, always the same in regard to absolute time. Out of these points, V is the initial point for the sāyana system, Z, that of Keropant's purely nirayaṇa system and S, that of the traditional nirayaṇa system. From this it is clear that so far as the accuracy of planetary positions is concerned, the almanac of any school can always stand the test of experience provided the astronomical works from which they are computed give correct planetary motions and accurate planetary positions for the chosen epoch. As the epochal positions and motions of planets in our works are not correct, our astronomers are prepared to correct the old works without altering the initial point of the ecliptic, and any sensible man will admit that rectification to that extent at least is absolutely necessary.

The phenomena of eclipses, conjunctions of planets and the heliacal rising and setting of planets depend upon the distance between two celestial bodies. Hence, they can be correctly calculated if only their epochal positions and motions are correct, irrespective of the question what point has been adopted as the initial point. Many people think, as the author used to think before he understood the theoretical aspect of this subject, that Keropant's almanac is correct because, it gives accurate moments of eclipses ; and this is being advanced as the main argument for accepting the almanac (Introduction to the almanac). This is very facile for hoodwinking ignorant people. Compilers of the sāyana almanac do not attach much importance to such claims. In the introduction to the sāyana pañcāṅga for Śaka 1807, it is remarked that as the nirayaṇa system is unscientific and the sāyana system is scientific,

the sāyana almanac should be accepted ; and if there is no means to calculate accurate positions of planets, a sāyana almanac should be compiled at least with the help of the Grahalāghava. Another argument usually put forth is that the nakṣatras are correctly obtained by following Keropant's almanac ; but it is not wholly true. It is quite possible to ensure the correct positions of nakṣatras even by maintaining the initial point adopted by the present-day almanacs. This point will be again discussed later. The only thing which must be stressed here is that whatever initial point is adopted for stating the positions of planets, if correct motions of planets are known, the positions of planets obtained from them will be found to agree with observations ; and the accuracy of the motions and positions of planets which is the main point of difference between the old and new almanacs is universally recognised as the most essential feature of the required data.

What is the Actual error in the Grahalāghava and other almanacs ?

It is desirable to know the extent of the actual error occuring in the calculation of tithis, planets etc., in the almanacs following Grahalāghava and other works. It shall be demonstrated here. Keropant's almanac and the five other modernized (accurate) nirayaṇa almanacs, as also the sāyana pañcāṅga mentioned above are at present compiled from the English *Nautical Almanac* or from the French *Connaissance des Temps* (Knowledge of Time). But their initial points are different from one another or from that of the *Grahalāghava*. It will be found from the explanation already given above with the help of a diagram (Page 292) that the actual extent of the error occurring in the Grahalāghava almanac cannot be estimated simply by comparing it with other almanacs. A *Grahalāghava* almanac has been attached to the sāyana almanac for Śaka 1808 ; and it is accompanied by a third almanac which is a modernized (accurate) nirayaṇa almanac ; it has been already seen by many. The portion for the bright half of Phālguna from the *Grahalāghava* and the modernized nirayaṇa almanac has been given in Appendix at the end. The modernized or accurate nirayaṇa almanac has adopted the same amount of ayanāṃśa as the *Grahalāghava*, (22°44′ for Śaka 1808). The Grahalāghava has adopted the length of the year laid down by the Sūrya-Siddhānta. If on this basis, 22°2′ had been taken as the ayanāṃśa, the error occuring in the *Grahalāghava* almanac would have been exactly detected. However, the actual error can be found out almost exactly even from the almanacs given in the appendix. Both the almanacs are calculated for the meridian of Ujjayinī and the time in ghaṭis and palas in both has been reckoned from the mean sunrise.

This will ensure a correct comparison when tithis are compared. We find the duration of the 9th lunar day of the bright half of Phālguna, falling on Friday, as given by the *Grahalāghava* almanac, is shorter than that given by the modernized (accurate) almanac by 13*gh*-45*pal* ; and in the case of the dark half (which is not shown in the appendix), the sixth lunar day is longer by 13*gh*-59*pal*. In the *Grahalāghava* almanac, the duration of *Mṛga* nakṣatra on the 9th lunar day is shorter by 15*gh*-24 *pal*, and that of the *Prīti* yoga as at the same time shorter by 17*gh*-23*pal*. The duration of the tithi, nakṣatra and yoga in ghaṭis does not generally err by more than this. The error reaches the maximum at about the 8th lunar day of the dark and bright halves ; and is minimum at about the full and new moons. The reason for this is tha the correction for the *equation of centre* for the moon's place at the lunation

as found from our works is not very erroneous (pages 246 and 247). Midway between the lunations the error in the moon's longitude amounts some-times to about 2° and sometimes even 3°. This causes so much variation in the ghaṭis showing the duration of tithi, nakṣatra and yoga. Our works give about 2°10′ as the maximum equation of centre for the sun, while the European tables give it as 1°55′ for the present time. On account of this, the sun's place is some- times found to be correct but sometimes in error by about 15 min. of arc. According to our astronomical works the minimum duration of the tithi is 54 ghaṭis and the maximum is 66 ghaṭis. But according to the *Nautical Almanac* these measures are 50 and 66 ghaṭis respectively. (This variation is due to the variation in Moon's place). This gives rise to a somewhat greater number of suppressed and duplicated tithis and nakṣatras in the almanacs calculated from the *Nautical Almanac*. During the 12 months in Śaka 1809, the Sāyana Pañcāṅga and the Keropant's Pañcāṅga gave 16 suppressed tithis and 10 duplicated tithis, while the Grahalāghava Almanac gave 13 suppressed and 7 duplicated tithis. In the modernized nirayaṇa almanac for Śaka 1808, the suppressed nakṣatras number 10 and the dupli cated ones number 13, while those in the Grahalāghava number 9 and 12 respectively ; the part of the *Grahalāghava* almanac for the bright half of Phālguna reproduced here shows that the error ir the position of Mars is 1°1′, that of Jupiter 3°26′, of Venus 1°6′, of Saturn 2°40′ and of moon's north Node (Rāhu) 41′. The error does not generally exceed these values. Mercury's place in the dark half is wrong by 3°31′. The error is sometimes found to be as much as 9°. The main reason for this divergence is the difference in the values of mean places according to the two systems. Similarly, it is partly due to the difference between the values of the equations of centre and the annual parallax. We have already discussed the question relating to the difference between the equations of centre (page 244).

Certain phenomena such as planetary conjunctions and the heliacal rising and setting of planets whereby the difference between the Sāyana almanac and the Grahalāghava almanac, can be easily realized by an observation of the sky, have been given in the column headed *ŚĀSTRĀRTHA* (*scriptural speciality, Phenomena etc.*), in the fortnightly portion of the almanac given in the appendix. A list of such phenomena for the whole year is given in the Sāyana almanac. Many people have verified that the calculation of these phenomena as given in the Sāyana almanac is correct while that in the Grahalāghava almanac proves to be wrong. Such a list for Śaka 1808 has been given in appendix. It has been verified by experience. The Grahalāghava almanac for Śaka 1806 had not shown any lunar eclipse in Caitra, while the sāyana and other modernized nirayaṇa almanacs like that of Keropant had shown a lunar eclipse as "grastodaya" (i.e. moon eclipsed at the time of rising). Again according to the Grahalāghava almanac for Śaka 1814, the lunar eclipse occurring in Vaiśākha was to end before sunrise ; while the sāyana and other modernized almanacs had shown the moon as setting in an eclipsed condition. On both these occasions, the phenomena as given by the sāyana and other modernized almanacs were confirmed by observation. Whatever applies to the Grahalāghava almanacs regarding visual proof or observation, applies with equal force to almanacs compiled on the basis of Makaranda and other works in other provinces. In short, the almanacs in current use all over our country do not appear to be correct in the light of observation of heavens. The motions

and positions of planets used by them must, therefore, be rectified. In other words, correct works must first be compiled in order to prepare the ground for correct almanacs. *The history of astronomy* which is given at the beginning of this part will show in various instances that our tradition favours the idea of applying corrections to older works while compiling new ones, the object being to ensure the agreement of calculated figures with the observed facts. The same process must be adopted to-day. This suggestion is acceptable to all, including even the *orthodox* astronomers.

Acceptability of the sāyana and nirayaṇa systems

Let us now consider the second point of difference between the old and new almanacs, viz. the length of the year and the corresponding variation in the ayanāṃśa figures. When this point is to be cosidered the sāyana almanac stands on one side and all other nirayaṇa almanacs, including the orthodox ones and the new ones like that of Keropant, stand on the other. So the question to be considered is which of the two systems is acceptable-Sāyana or Nirayaṇa ? The question will have to be considered in it's *FOUR ASPECTS* : *logical, historical, religious* and *practical.*

Preamble

In the beginning, one or two facts must be noted for the proper understanding of the subject. The day on which the 'day' and the 'night' are of equal length is called the equinoctial day. On the days when the sun comes to either of the equinoctial points, it would transit the points 'V' and 'A' in the diagram (page 292) and the equinoxes will then occur, and when it moves away from the equinoxes to a distance of three signs, it reaches 'N' and 'S' and brings about the 'solstices'. All the four points have the same rate of displacement as the precession of the equinox. Hence, the equinoctical and solstitial positions and the lengths of day and night depend upor the sāyana place of the sun. The sun moves in the northern hemisphere from his position at the vernal equinox to that of the autumnal equinox ; and it is in that very period that in our country the length of the day is greater than 30 ghaṭis, and the following seasons occur : *part of Spring, Summer, the Rains* and *part of Autumn.* Apart from the fact that the beginning and end of these seasons vary a little in the case of particular places due to special reasons, the above fact holds good as a general rule. Hence, even the seasons depend upon the sāyana position of the sun. In our country, we have the spring season when the sun comes to the vernal equinox and the rainy season has just set in, when the sun reaches the summer solstice irrespective of the stellar nakṣatra to which the sun may come. Modern astronomy has discovered that the equinox makes a complete revolution through the *steller zodiac.* The nirayaṇa Aśvinī nakṣatra division and the Meṣa sign began from the equinox about Śaka 444. According to the formula, that lunar month is to be termed Caitra in which the sun transits the first point of Meṣa. The first point of the current nirayaṇa system is 22° and that of the Keropant's system 18° to the east of the equinox. As time passes, it is bound to move three signs away from the equinox, i.e., if will coincide with the summer solstitial point. When it shall have shifted so far, the sun's ingress into that point will no doubt coincide with the rainy season ; and as the sun would then be reaching the initial point of the Nirayaṇa Zodiac, it would be the moment of Aries ingress and by formula, the month of Caitra. It is an indisputable fact that in course of time, the nirayaṇa Caitra

will fall in the rainy season. It is now-a-days a fact of actual observation that the equinoxes and solstices occur 22 days, corrosponding to the 22° of ayanāṃśa, before the sun enters the nirayaṇa Meṣa, Karka, Tulā or Makara and this fact has already been mentioned in the Siddhānta works. Bhāskarācārya, in the chapter on true positions in the Sid. Śiromaṇi, says,

क्रियतुलाधरसंक्रमपूर्वतो ऽयनलवोत्थदिनैर्विषुवद्दिनं ॥
मकरकर्कटसंक्रमतो ऽयनं · · · · ॥ ४५ ॥

सि. शि. स्पष्टाधिकार.

Even then, the Jośīs (almanac-makers) whose study does not go beyond the Grahalāghava, do not understand this. Even among other people there are very few who understand this. In this province almanacs based on Grahalāghava mention the winter and summer solstices as occurring on the days of the sun's entry into the (nirayaṇa) signs of Capricorn and Cancer, and not 22 days earlier. How astonishing it is that even the Keropant's almanac now-a-days shows the solstices against the days of the sun's ingress into the nirayaṇa Capricorn and Cancer of that almanac, that is, 18 days later than the day they are actually seen to occur in the heavens. It is not less astonishing to note also that Bāpūdeva omits the *ayanas* (Solstices) altogether. The Caṃḍū almanac gives the correct days of the 'ayanas', a matter which puts other compilers to shame. It mentions even the entry* of the sun into all the 12 sāyana signs. The Siddhāntic almanacs of the Madras side show all the sāyana-saṃkrāntis (solar ingresses) by terms like "Meṣāyanaṃ, Vṛṣāyanaṃ", etc. An almanac for Śaka 1758 in manuscript form and compiled all Bijapur has come to the notice, whereir all the 12 sāyana solar ingresses have been denoted as Meṣāyana etc.

The Sāyana System

The system adopted by the compilers of the sāyana-almanac (Lele, Moḍak and the author) is as follows :—

The year adopted is tropical. The first nakṣatra division reckoned from the equinox is termed Aśvinī, and the first sign so reckoned is Meṣa, irrespective of any star occupying the part ; following the same principle the solar ingresses are determined from the sun's entry into the sāyana (tropical) signs, and the lunar months receive their names on the basis of these ingresses. Thus the lunar month in which the sun enters the sāyana sign of Meṣa, which is the same thing as the sun's coming to the vernal equinox, is to be called Caitra and so on. By this system, the spring season will always be found to occur in Caitra, the rain will be starting on the Ārdrā nakṣatra, and consequently all the seasons will continue to occur regularly in the months assigned to them.

Logical Aspect

Let us first consider the question of the acceptabiity of the sāyana and nirayaṇa systems from the logical point of view. Just as the sunrise is the natural means for measuring the day, the fullness or invisibility of the moon for measuring the month, so the cycle of seasons is the natural means for measruing

*The author has a copy of Caṃḍū almanac for Śaka 1806. It has indicated solar ingrosses in nirayaṇa signs by such words as 'Arka in Meṣa, Arka, in Vṛṣa, etc. and those into sāyana signs by the words "Bhānu in Meṣa, Bhānu in Vṛṣa" and so on, using two synot nyms for the Sun (Arka and Bhānu) for the sake of distinction.

the year. The seasons are caused by the Sun. If the seasons had not been occurring, the year as a unit of time would not have come into existence. Hence, the year must be reckoned by a solar measure, and because, the seasons follow the sāyana positions of the sun, the year must be reckoned on the tropical basis. Moreover, the seasons do not complete their cycle during the period of twelve lunar months, and hence, an intercalary month has to be inserted. If the intercalary month is not inserted, then all the seasons will be found to occur successively in Caitra, during a peiod of 33 years, just as the Muslim month of Muharram moves through all the seasons during 33 years. Hence, the object of inserting an intercalary month is nothing else but to see that a particular season should always occur in a particular month ; and because the seasons depend upon the sāyana positions of the sun the adoption of the system of intercalary months virtually means the acceptance of the sāyana system in principle. Just as, if the intercalary month is not inserted, all the seasons will be successively occuring in any one of months, they will successively occur in the same month during a period of 26000 years if the sidereal year is adopted. For instance, if the Spring season occurs at a certain time in Caitra, Summer would begin to occur in that month after 4.25 thousand years, the rainy season after 8.5 thousand years and winter after 17 thousand years. If we insert sn inercalary month to prevent the dissociation of seasons from the months assigned to them we must accept the sāyana system to forestall the irregularity which is bound to occur undoubtedly, even if it does so after the lapse of many many years.

Historical Aspect

These two facts ought to suffice as proofs of the acceptability of the sāyana system. Let us, however, see what tradition has to say in the matter. The tropical year is a natural one. Hence, ever since man began to use 'year' as the time-unit after the creation of the world, the tropical System must have come into vogue ; and it has been explained in detail in the Conclusion of Part I that it actually did come thus into vogue and was prevalent during most of the Vedic period (page 141 of Part I). In the beginning they must have been reckoning the year from the cycle of seasons by inserting an intercalary month, before the terms Madhu, Mādhava etc. became current, which means that the sāyana system itself was in use in somewhat crude form. Later on when the terms Madhu, Mādhava etc. came into use, the measure of the 'sāyana' year may have become fairly accurate. This measure later on continued for centuries till the names Caitra, Vaiśākha etc. became current. The foundation of the nirayaṇa system was laid about 2000 B.C. when the terms Caitra, Vaiśākha etc. were introduced, (page 132 & 140 of Part I). According to Vedāṅga Jyotiṣa the year began at the beginning of the Dhaniṣṭhās. This is a nirayaṇa measure. But it mentions at the same time that the year began with the winter solstice. Now, while the stars in the vicinity of the sun are not visible, even an ignorant person can more easily tell when the winter solstice occurs rather than when the Sun reaches the beginning point of the Dhaniṣṭhās. This shows that in actual practice they must have been starting the year at the beginning of the Ayana (Solstice) itself. The system prevalent in the Vedāṅga Jyotiṣa period was very erroneous, as has already been pointed out before (page 93 of Part I). Hence, it seems more probable that the system must have been kept in working order by inserting 35 instead of 38 intercalary months during 95 years and by beginning the year at the time of winter solstice. This means that the tropical year enjoyed the vogue for all practical purposes.

Most of the works compiled in the Vedāṅga period mention the year as beginning with the Spring. So then during the Vedāṅga period the sāyana year was accepted for practical purposes or at any rate it was intended to be so accepted.

Let us now cosider the system in use during the Jyotiṣa siddhānta period. The Sūrya Siddhānta contains the following lines :—

भचक्रनाभौ विषुवद्वितयं समसूत्रगं ।। अयनद्वितयं चैव चतस्रः प्रथितास्तु ताः ।। ७ ।।

तदंतरेषु संक्रांतिद्वितयं द्वितयं पुनः ।। नैरंतर्यात् तु संक्रांतेर्ज्ञेयं विष्णुपदीद्वयं ।। ८ ।।

भानोर्मकरसंक्रांतेः षण्मासा उत्तरायणं ।। कर्कादेस्तु तथैव स्यात् षण्मासा दक्षिणायनं ।। ९ ।।

मानाध्याय.

"(7) On the hub of the wheel of nakṣatras are situated pairs of equinoctial and solstitial points, placed regularly. These are the four main (famous) transits of the sun.

(8) In the interval of each pair are situated pairs of two saṃkrāntis known as Viṣṇupadīs.

(9) The period of six months known as Uttarāyaṇa begins from the moment of the sun's transit into the sign of Makara (Capricorn) ; similarly, the period of six months known as Dakṣiṇāyana begins from the sun's transit into Cancer".

Chapter on measurements.

Here the words Cancer and Capricorn's ingress must be taken to be 'sāyana' since, otherwise, the words "Winter solstice occurs at the sun's entry into Capricorn" would carry no sense. Now one might argue that these are the views expressed at a time when the shifting of the ayana points was not known. Even accepting this as correct, the above verses suggest that two 'ayanas' make a year. This assertion and the next verse given below shows that the sāyana system itself was acceptable to the Sūrya Siddhānta. The verse runs thus :—

द्विराशिनाथा ऋतवस्ततोपि शिशिरादयः मेषादयो द्वादशैते मासास्तैरेव वत्सरः ।। १० ।।

Meaning :—"The winter (Śiśira) and other seasons are formed by groups of two months, each beginning from it (i.e. Capricorn). These are the twelve months beginning from Meṣa. They make a year".

This defines the year as a cycle of season comprising 12 months. Thus the Sāyana system was acceptable to the Sūrya Siddhānta in principle. Again, it has been shown in detail in our review of Brahmagupta's work (pages 83 to 85) that Brahmagupta held that the solar year commenced on the equinoctial day, which obviously means that he preferred the tropical year. Further more, the length of the year adopted by our astronomical works is greater than that of the true sidereal year by about 8 pals. Hence, it cannot be said that the year must be necessarily sidereal. As the star with which the Sun is conjoined is not visible, it would be easier to determine the length of the tropical year than that of the sidereal year ; and it is more probable that, just as Brahmagupta determined the length of the year from the Sun's conjunction with the equinox, the earlier astronomers also may have determtned it in the same way ; in other words, it seems to have been their object to accept the sāyana year measure in principle. Hence, although the ultimate result amounted to the adoption of the sidereal year or something very akin to such adoption owing to the fact that the terms Caitra, Vaiṣākha etc. became current during the time between the end of the Vedic period and the time when the

shifting of equinoxes became known, and that the adopted year measure was nearer to the sidereal than to the tropical year, there is no doubt the object of the ancients was definitely to adopt the tropical year. And it was but natural to have such an object in view, for no one would like to see rainy season occurring in Caitra.

Our people came to know about the correct rate of the shifting of the solstitial points in the 7th century of the Śaka era (page 220). Eminent astronomers like Bhāskarācārya lived during the period that followed and it is true that they did not abandon the nirayaṇa system even though they could have known the effects of adopting it. It appears that they could not venture to adopt the sāyana system, because they feared that the rejection of the traditional nirayaṇa system would cause a confusion in every day affairs by disturbing the system which was in use continuously. The reasons in those days also did not show any appreciable variation, while they have actually mentioned when the solstices and equinoxes really occur. Again, most of them thought that the equinox does not make a complete revolution but an oscillatory motion. They appear to have failed to adopt the sāyana system for this reason also.

The students of European astronomy have now come to know that the equinox makes a complete revolution. Let us therefore, consider the views of the present astronomers. Of the two well known astronomers who lived in this period, Bāpudeva and Kero Lakshman Chhatre, the views of Bāpudeva have already been cited above (page 286). He has stated that although the sāyana system was the supreme system, he had compiled the almanac by the nirayaṇa system because it was in use all over the country. In addition to this he also expressed the view that astronomers living seven or eight centuries later would devote due consideration to the question. Let us now see what Keropant's views are. A controversy over this question took place in 1883 A.D. between Keropant and the followers of the sāyana system through the *Aruṇodaya* newspaper of Thana. He writes in the issue of the *Aruṇodaya* dated the 4th November, 1883, "As regards my own opinion, the most reasonable method cf mesuring the motions of moving bodies to compare their positions with those of stationary objects ; to compare them with other moving bodies is not right. The sun, moon, planets, equinox etc. all have motion. In order to determine their positions, they must be compared with the stars as they are fixed. But in order to ensure an easy process or in special cases where there is some difficulty, this method is to be discarded and the motions of other moving objects are to be determined with respect to objects which are also moving. For example, although the stars are fixed.......... we have to take an imaginary Sun moving at the mean rate of motion in order to determine the beginning of the day. From this point of view, as the seasons depend upon the moving equioxes, I am myself of opinion that it is desirable to begin the year with respect to equinox. Still, the prevailing tendeney is not to practise anything if it is contrary to convention even though it is pure or rational. Has anyone ever considered which of these systems is wrong, which is easy and which is complicated, or which is scientific and which is unscientific ? We follow the system which suits the occasion." In this statement of Keropant, most note-worthy thing is his admission that although the seasons depend upon the equinoxes, that is on the sāyana position of the sun, the fear of breach of convention stands in the way of adopting the tropical year.

In 1893 A.D., an article on the question of the sāyana-nirayaṇa system had appeared in two issues of the *Kesari* of Poona. A part of it is quoted here. Prof. Tilak, the editor of the Kesari wrote, "Seasons depend upon the position of the equinoctional point————It must be the month of Caitra, if the spring season commences when the sun is in Aśvinī........ After 2000 years (Spring) will begin on the first lunar day of bright half of Phālguna........After 4000 years it will begin from the first lunar day of the bright half of Māgha..........."It is evident from calculation, that if the present nirayaṇa system be allowed to continue, the rains will set in Caitra as time passes on. There is absolutely no doubt about it. The quotations have been given from the writings of mathematicians like Keropant and Tilak in order to convince even those who have either no leisure to enter into intricacies of calculations or who are not well grounded in mathematics.

Keropant and Tilak hold the view that the present nirayaṇa system should be allowed to continue in a modified form. Hence, their admission about the validity of the claims made by the compilers of the sāyana almanacs, in respect of seasons particularly, carries weight.

Keropant and Tilak have suggested a way for maintaining the nirayaṇa system ; but it is not acceptable. More about it will be given later.

Ārdrā, the first Nakṣatra of the Rainy Season

Some people think that the beginning of the rains has been permanently linked with the sun in Mṛga nakṣatra ; they do not understand how they wil ever begin with the sun in Aśvini. But 1400 years ago, Mṛga was not at all the nakṣatra indicating the advent of the rains. Our astronomical works have mentioned Ārdrā as the first nakṣatra indicating the advent of the rains. The almanacs give a forecast for the whole year, which includes a forecast of the rains based on the moment of the sun's entry into Ārdrā nakṣatra division ; not only this, but the ruler of the day of the week on which the sun enters the Ārdrā division is regarded as the lord of the clouds. This shows that formerly Ārdrā was the first nakṣatra of the rainy season and Mṛga took its place later ; similarly the beginning of the rains will gradually take place retrogressively with the sun in Rohiṇi, Kṛttika and ultimately, after some years, in Aśvini, that is in Caitra. This confusion will not arise if nakṣatra divisions are made on the sāyana basis.

Dates for Mṛga Nakṣatra

Some people think that the sun's entry into Mṛga takes place on June 5, that this rule will never be falsified and that the rains also will not fail to come on the right day. But as the Christian year is tropical, the sun's entry into a nirayaṇa nakṣatra division will not take place on the same date perpetually, Before Śaka 1707, the sun's entry into Mṛga used to take place on the 4th or 5th of June. Later on it began to occur on the 5th or 6th. From Śaka 1819 onwards it will cease to occur on the 5th and will take place either on the 6th or 7th of June. In short, tradition is favourable to the acceptance of the sāyana system.

Religious Aspect

The religious point of view has been considered at some length in the course of the above discussion and even before. Let us now consider it in somewhat greater detail. Quotations from Vedic Literature, like—

"Madhuśca Mādhavaśca Vāsantikāvṛtū" Tai. Saṃ. 4-4-11.

which mention the names of months relating to all the six seasons, have

been already given (page 18 of Part I). Accordingly the spring season must be found in the months of Madhu and Mādhava for all time.

अश्वयुज्यामाश्वयुजीकर्म ॥ १ ॥ आहिताग्नेराग्रयणस्थालीपाकः ॥ ४ ॥

आश्वलायनगृह्यसूत्र, अध्या. २ खंड २.

The compiler of the sūtra enjoins the preparation of the "sthālipāka" for the full moon day of Āśvina. It is well known that it requires newly harvested corn.

मार्गशीर्ष्यां प्रत्यवरोहणं चतुर्दश्यां ॥ १ ॥ पौर्णमास्यां वा ॥ २ ॥

··हेमंतं मनसा ध्यायेत् ॥ ५ ॥

आश्व. गृ. सू. २.३.

"The rite known as Pratyavarohaṇa, is to be performed in Mārgaśirṣa, on the 14th lunar day or on the full moon day..........and the season of Hemanta should be remembered."

This rite of Pratyavarohaṇa in Mārgaśirṣa is to be performed in honour of the Hemanta deity. This suggests that season of Hemanta should come in Mārgaśirṣa.

अथातोध्यायोपाकरणं ॥ १ ॥ ओषधीनां प्रादुर्भावे श्रवणेन श्रावणस्य ॥ २ ॥

आश्व. गृ. सू. ३.५.

In this it has been ordained that the rite of Upākarma should be performed in Śrāvana when fresh herbs grow in abundance. This obviously means that there must be rainy season in Śrāvana. Many such quotations from different *sūtra-works* could be given which indicate that a particular season must be current in a particular month.

Now I quote a few lines from Purāṇas and other works mentioning the rites that are to be performed in particular months and particular seasons.

अशोककलिकांश्चाष्टौ ये पिबंति पुनर्वसौ ॥ चैत्रे मासि सितेऽष्टम्यां न ते शोकमवाप्नुयुः ॥

प्राशनमंत्रः— त्वमशोकवराभीष्टं मधुमाससमुद्भव ॥

लिंगपुराण.

"Those who drink the juice of eight flowers of Aśoka tree in the Punarvasu nakṣatra, in the month of Caitra on the 8th lunar day, will not come to sorrow.

The mantra to be chanted :—"Oh blessed Aśoka tree, who is created in the month of Madhu".

Herein has been mentioned the chewing in Caitra of the 'Aśoka Kalikā' which grows in Spring.

अतीते फाल्गुने मासि प्राप्ते चैव महोत्सवे ॥ पुण्येन्हि विप्रकथितं प्रपादानं समाचरेत् ॥

तसेंच, प्रपा कार्या च वैशाखे देवे देया गलंतिका ॥ उपानद्व्यजनछत्रसूक्ष्मवासांसि चंदनं ॥ १ ॥

जलपात्राणि देयानि तथा पुष्पगृहाणि च ॥ पानकानि विचित्राणि द्राक्षारंभाफलानि च ॥ २ ॥

मदनरत्ने.

"A water tap should be offered on an auspicious day recommended by a Brāhmaṇa when the month of Phālguna is elapsed and rejoicings begin.

Again arrangement to distribute cold water should be made in Vaiśākha, the water pots should be hung over idols for water to trickle over them and the following articles should be given to Brāhmaṇas :—Shoes, fans, umbrellas, fine garments, sandalwood, water vessels, bowers etc."

This indicates that the hot season should always be found in Caitra and Vaiśākha.

शरत्काले महापूजा क्रियते या च वार्षिकी । आश्विने मासि मेघांते

देवीपुराण.

"The great annual worship which is performed in autumn, in the month of Āśvina, after cloudy season has passed."

This shows that the season of Śarat should always be found in Āśvina.

मेषादौ च तुलादौ च मैत्रेय विषुवस्थितः । तदा तुल्यमहोरात्रं करोति तिमिरापहः ।।

अयनस्योत्तरस्यादौ मकरं याति भास्करः ।।

विष्णुपुराण.

It shows that the sun's ingress into Meṣa and Tulā must occur on the equinoctial days and that the ingress into Makara on the day of the winter solstice, and these are not possible without taking the ingress on the sāyana basis.

The above quotations from Śrutis, Smṛtis, and Purāṇas show that spring and other seasons must always occur in Madhu and other months i.e. in Caitra and other months ; and this is not possible unless we accept the sāyana system.

In the face of the above quotations it is not necessary to give further quotations from astronomical works or any other astronomical quotations in support of our contention. But works on Dharmaśāstra give even such quotations to strengthen their argument and hence some of them are given below.*

यस्मिन् दिने निरंशः स्यात् संस्कृतोर्कोयनांशकैः ।। तद्दिनं च महापुण्यं रहस्यं मुनिभिः स्मृतं ।।

ज्योतिर्निबंधे वसिष्ठ.

That day has been regarded as very sacred by sages, on which, the longitude of the sun, after the ayanāṃśa correction is applied to it, becomes zero.

This emphasises the sanctity of the equinoctial day.

अयनांशसंस्कृतो भानुर्गोले चरति सर्वदा ।। अमुष्या राशिसंक्रांतिस्तुल्यः कालविधिस्तयोः ।।

स्नानदानजपश्राद्धव्रतहोमादिकर्मभिः सुकृतं चलसंक्रांतावक्षयं पुरुषोऽश्नुते ।।

पुलस्त्य.

"The sun, after receiving the correction of ayanāṃśa, always moves on the (celestial) globe. The 'rāśi-saṃkrānti' is to be regarded as secondary. The performance of rites on both the occasions is said to be the same. But a person 'obtains inexhaustible stock of 'merit' if he performs the following rites on the 'chala (moving) saṃkrānti' :—bath charity, penance, śrāddha, vrata, homa (sacrifice) etc.—Pulastya."

चलसंस्कृततिग्मांशोः संक्रमो यः स संक्रमः ।। अजागलस्तन इव राशिसंक्रांतिरुच्यते ।।

पुण्यदां राशिसंक्रांतिं केचिदाहुर्मनीषिणः ।। नैतन्मम मतं यस्मान्न स्पृशेत्क्रांतिकक्षया ।।

वसिष्ठ.

*Most of the quotations have been taken from Pīyūṣadhārā, a commentary on Muhūrtacintāmaṇi (Śaka 1525).

"The ingress of the 'chala' sun into a rāśi is the real saṃkrānti while the **rāsi saṃkrānti** is like the mane of a goat. Some wise men recommend the rāśi **saṃkrānti**. But I do not agree with it, since it is not touched by the ecliptic arc."

संस्कृतायनभागार्कसंक्रांतिरत्वयनं किल ॥ स्नानदानादिषु श्रेष्ठा मध्यमः स्थानसंक्रमः ॥

सामसिद्धांत.

अयनांशसंस्कृतार्कस्य मुख्या संक्रांतिरुच्यते ॥ अमुख्या राशिसंक्रांतिस्तुल्यः कालावधिरतः ॥४७॥

रोमषसिद्धांत, **पष्टाधिकार**

चलसंस्कृततिग्मांशोः संक्रमो यः स संक्रमः ॥ नान्योन्यत्र च तत्क्षेत्रं नैति तत्क्रांतिरक्ष**या** ॥ ६२ ॥

शाकल्यसंहिता तृतीयाध्याय

Some of the above quotations show that 'rāśi-saṃkrāntis' or ingresses into nirayaṇa *rāśis* must be rejected and only those into the tropical signs are worth accepting. Some of them state that *rāśi-saṃkrāntis* are inferior as compared with the Sāyana saṃkrantis. According to some authors, some of the above quotations are simply laudatory. As, however, the sanctity of the equinoctial and solstitial days has been recognized by the Purāṇas and many other works, the compilers of works on the Dharmasāstra could not discard them even though they occur before the nirayaṇa saṃkrāntis into Aries-Libra and Cancer-Capricorn. Hence, while describing the holy periods related to nirayaṇa-saṃkrāntis, they had to add the remarks "The same holds good in regard to ayaṇas" and some compilers of works on the Dharamśāstra who had no knowledge of astronomy, even imagined 12 ayanas to be known as "Meṣāyana, Vṛṣāyana" etc. corresponding to Meṣa and other Saṃkrāntis. It has been already mentioned above (page 298) that even some nirayaṇa almanacs give the tropical ingresses in this way or in some other words, the compilers of almanacs on our Bombay-Poona region, however, do not grant the public of Maharashtra even this modest favour. The Dharmaśāstra experts* in these parts, however, definitely know that such rites, as holy 'baths and charitable offerings, have been recommended even for the occasion of tropical ingresses. The '96-śrāddha' rites known as 'ṣaṇṇavati śrāddhas, and to be performed during the year include the śrāddhas for the occasions of saṃkrāntis and these are only 12 and not 24. Accordingly only 12 saṃkrantis of some kind ought to be admissible for other religious rites as well.

In short, the sāyana almanac shows the proper time for religious observe-tions as ordained by the Śrutis, Sutras, Smṛtis and Purāṇas, and it should, therefore, be acccepted for everyday use.

Doubts Resolved

Let us first consider the objections raised against the sāyana system, before we proceed to consider the practical aspect of the system. The same star is not always found near the equinox. The equinox is receding with respect to the visible stars ; and when the tropical year is accepted, any star will happen to come in the place of the equinox. Some years ago the star Revatī was conjoined with the vernal equinox ; at the present time the equinox occurs near the star Uttarā Bhādrapadā. After the lapse of a number of years it will occur in the Purvā Bhādrapadā, and it will be gradually receding in this

*On the occasion of the debate on the sāyana almanac held in 1884 during the Vasantot-sava in Poona, Gangadhar Shastri Datar, the eminent scholar, well versed in the Dharma-shastra and the Vedas had admitted that the almanacs ought to mention sāyana —Saṃkrāntis.

way when the equinox would come in the Pūrvā Bhādrapadā, that nakṣatra division will have to be called 'Aśvinī' while Phālgunī will have to be called the 'sāyana citrā' and this terminology has been adopted even now by the sāyana almanacs. If one refers to the conjunctions of the moon with the stars given in these almanacs, one would find that when the moon is conjoined with the star Uttarā-Phālgunī, the diurnal nakṣatra (*i.e.* the nakṣatra division occupied by the moon) is shown to be Citrā. Thus a planet will have to be taken to be occupying one nakṣatra when it is actually conjoined with quite a different star.

SĀYANA SYSTEM DISPLACES STARS

In this way the stellar (visible) nakṣatras will be dissociated from the nakṣatra divisions of the same name. The name Mṛgaśīrṣa, Hasta etc. show that the nakṣatra divisions originally derived their names from the stars and not on the principle that a certain region was to be known as a certain nakṣatra regardless of the star in that region. It has also been mentioned in Part one (page 48) that some of the names of nakṣatras found in the Vedas are in the singular number, some in dual and some others in plural. From this it is clear that the nakṣatra names were originally suggested by the stars. In the same way the names, Caitra, Vaisākha etc. were originally determined from those of stellar nakṣatras.

CAITRA AND OTHER NAME WILL NOT BE JUSTIFIED

But if the sāyana system be adopted the equinox would be in Pūrvā Bhādrapadā ; and when the sun is situated near the stars of Purvā Bhādrapadā, the (solar) nakṣatra would receive the name "Sāyana Aśvinī" and when the Moon becomes full near the star 'Pūrvā Phālgunī, which is 13½ nakṣatra divisions away from it, the lunar month would be called Caitra, because the (Moon's) nakṣatra would receive the name 'sāyana Citrā' and because the solar ingress into sāyana Meṣa would take place in that lunar month. Thus, though the month should have properly been called Phālguna because of the full moon's proximity to the Pūrvā Phālgunī star, it will have to be called Caitra. Thus, considered from the purely sidereal (nirayaṇa) point of view even the months receive wrong names in the sāyana system.

If the sāyana system be accepted the seasons will be found to be in their proper place. For instance, Spring will always occur in Caitra and Vaiśākha but the stellar nakṣatras will go wrong. Any star which happens to be near the equinox will have to be called* 'Aśvinī' despite the star that may be there, and though the names Caitra, Vaiśakha etc. were originally associative, they will have to be regarded as merely technical and conventional and the (Lunar) months Phālguna, Māgha etc. which at present receive these names because of their association with stars, will gradually come to be called Caitra. If the names Madhu, Mādhava etc. suggesting seasons be revive and the terms Caitra, Vaiśākha etc. be discarded, then only will this verbal solecism disappear. But then would be Caitra and other names have become so deep-rooted that it would be difficult to eliminate them. It is also true that the nakṣatras do not have a set of alternative names suggesting seasons just as the months have Madhu and other names. The terms Meṣa Vṛṣabha etc. were divisional from the very beginning. Even if they be not so, they have been used in our astronomical works in the sense of divisions at least for the last 2000 years. There can be no harm if they are applied to the sāyana signs also.

*The maximum distance between Sāyana and Niryana nakṣatras will be 13½ nakṣatra divisions. Hence, the Chaitra nakṣatra division will be called Aśvinī when the equinox reaches that star after 12000 years.

Seasons Displaced by Nirayaṇa System

Now if the nirayaṇa system be adopted, the seasons will be displaced. Spring, summer and other seasons will gradually begin to occur in Caitra and the month of Caitra, even though it will witness the advent of rains, will have to be called Madhu. Not only that, but the rainy season will present a difficulty in the performance of religious ceremonies, like thread ceremony, marriage etc. which are to be performed in Māgha, Phālguna, Caitra, Vaiśākha and Jyaiṣṭha ; and although from the point of view of seasons, Āṣāḍha and other months will be favourable for them, their performance will still be difficult as our Dharmaśāstra prohibits them during these months.

Where, then, is the way out ? One is simply non-plussed if an attempt is made to find out a solution by which both the seasons and nakṣatras would be correctly represented. If it is a fact that the equinox makes a complete revolution, it is obviously impossible to find an adjustment for both. Hence it is necessary to effect some sort of compromise. We must first decide what we can afford to abandon : the seasons or the stellar nakṣatras—and then abandon it. There can be no other alternative. So let us see what we can afford to lose.

NAKṢATRAS DISPLACED EVEN IN NIRAYAṆA SYSTEM

Even to-day we are leaving the stellar nakṣatras. They are not all situated at equal distances. Hence, even the nirayaṇa almanacs have been required to divide the ecliptic into 27 equal parts and call them nakṣatras. Some of the 27 divisions include the junction star of two nakṣatras, while there are others which include none. A table has been given on page 308/309, to make this point clear by figures. The table shows the extent of each divisional nakṣatra, accurate nirayaṇa longitudes of the junction stars of nakṣatras, that is, their actual distances* from the junction star of Revatī and the polar longitudes of the nakṣatras (stars) according to the Grahalāghava. It has already been mentioned before that the initial point of our siddhānta works is movable. The initial point, according to the Sūrya-Siddhānta, was situated at a distance of 21° 27′ 9.8″ to the east of the equinox in Śaka 1772. The distances of the Junction stars from this point in that year have also been given in the table and it is also shown which junctions of nakṣatras are not situated in their respective divisions, but in advance of or behind them.

It would be clear from that, even according to Keropant's accurate measures or the genuine nirayaṇa system, 9 stars out of 27 are situated in advance of their divisions and 2 are behind, which means that 11 nakṣatras are occupying wrong places. When the diurnal nakṣatra is Aśvinī, the moon is not actually conjoined with any star, and when it is Citrā, she is conjoined with three stars, Hasta, Citrā and Svātī. Now it is true that if the true nirayaṇa year measure and the true precessional motion be taken, this error will always be the same and will never exceed. Even then if the adoption of most accurate and correct nirayaṇa system results in the displacement of 11 nakṣatras out of 27, of what avail is such a nirayaṇa system ? The longitudes of nakṣatras as given by the Grahalāghava are not true for the present time. Even if they are supposed to be correct, it is seen that six nakṣatras (stars) are wrongly placed.

* Keropant's Planetary Tables contain on pp. 324/325 the tropical longitudes of junction stars for Saka 1772. These distances have been obtained by subtracting the longitude of Revatī from them. Keropant has given 17°46′ as the longitude of Revatī. But accurate calculation shows that in Saka 1772 it was 17°46′ 44″. It has therefore, been taken as 17° 47′. Similarly the longitudes of Aśvinī, Jyeṣṭhā, P. Āṣādha, Sravaṇa, and Dhaniṣṭhā, are wrong as given by Keropant. Those have been corrected before use for the table below. As for the junction stars the same stars have been adopted as in Keropant's.

Serial No.	Nakṣatra	Extent of Divisional Nakṣatra: Begin		End		Positions of Junction Stars: Accurate Nirayaṇa (By Keropant)		Ahead of or Behind Division	According to Grahalāghava	Ahead of or Behind Division	According to S.S. in Śaka 1772		Ahead of or Behind Divn.
		°	′	°	′	°	′		°		°	′	
1.	Aśvinī	0	0	13	20	14	6	Ahead	8		10	26	
2.	Bharaṇī	13	20	26	40	27	4	Ahead	21		23	24	
3.	Kṛttikā	26	40	40	0	40	7	Ahead	32		36	27	
4.	Rohiṇī	40	0	53	20	49	55		49		46	15	
5.	Mṛga.	53	20	66	40	62	18		62		58	38	
6.	Ārdrā	66	40	80	0	67	6		66	Behind	63	26	Behind
7.	Punarvasu	80	0	93	20	93	22	Ahead	94	Ahead	89	42	
8.	Puṣya	93	20	106	40	108	50	Ahead	106		105	10	
9.	Āśleṣā	106	40	120	0	111	0		107		107	20	
10.	Maghā	120	0	133	20	129	58		129		126	18	
11.	P. Phalgunī	133	20	146	40	143	32		148	Ahead	139	52	
12.	U. Phalgunī	146	40	160	0	151	45		155		148	5	
13.	Hasta	160	0	173	20	173	35	Ahead	170		169	55	
14.	Citrā	173	20	186	40	183	58		183		180	18	
15.	Svātī	186	40	200	0	184	22	Behind	198		180	42	Behind

Serial No.	Nakṣatra	Extent of Divisional Nakṣatra: Begin		End		Position of Junction Stars: Accurate Nirayaṇa (By Keropant)		Ahead of or Behind Division	According to Grahalāghava	Ahead o, or Behind Division	According to S.S. in Śaka 1772		Ahead of or Behind Divn.
		°	′	°	′	°	′		°		°	′	
16.	Viśākhā	200	0	213	20	211	8		212		207	28	
17.	Anurādhā	213	20	226	40	223	19		224		219	39	
18.	Jyeṣṭhā	226	40	240	0	229	53		230		226	13	Behind
19.	Mūla	240	0	253	20	243	26		242		239	46	Behind
20.	P. Āṣāḍhā	253	20	266	40	254	42		255		251	2	Behind
21.	U. Āṣāḍhā	266	40	280	0	260	18	Behind	261	Behind	256	38	Behind
22.	Śravaṇa	280	0	293	20	281	52		275	Behind	278	12	Behind
23.	Dhaniṣṭhā	293	20	306	40	297	30		286	Behind	293	50	
24.	Śatabhiṣaj	306	40	320	0	321	42	Ahead	320		318	2	
25.	P. Bhādrapadā	320	0	333	20	333	36	Ahead	325		329	56	
26.	U. Bhādrapadā	333	20	346	40	354	13	Ahead	337		350	33	Ahead
27.	Revatī	346	40	0	0	0	0		360		356	20	

It has been proved (page 219) before that the initial point obtained from our works moves in advance of the junction star of Revatī by $8\frac{5}{10}$ seconds. The above table will show that the junction stars of seven divisions out of 27 divisions, made from the initial point of the modern Sūrya-Siddhānta, are found *behind* their respective divisions ; hence, when the 'diurnal nakṣatra' is Mṛga, the moon is actually conjoined with two stars, Mṛga and Ārdrā. The same thing happens in the case of seven nakṣatras. After 5000 years more, all stars except that of Uttara Bhādrapadā will fall behind their own divisions ; and then one will see the conjunction of the moon with Bharaṇī when the diurnal nakṣatra would be Aśvinī. Similar will be the case with 26 nakṣatras. The same thing will happen in the case of even Uttara Bhādrapadā after 7400 years. In short, even the prevalent nirayaṇa system will cause disorganisation of nakṣatras like that caused by the sāyana system.

If the term 'conjunction' be defined as the "phenomenon in which the longitudes of two celestial bodies are equal", then it would be the case of a *conjunction in longitude*. If it be defined as the position in which the right ascensions (R.A.) of two celestial bodies are equal, then it will be the case of *a conjunction in R.A.* The sāyana almanac gives conjunctions in right ascensions. Even the nirayaṇa almanac gives conjunctions in right ascension. That almanac has been compiled from the Nautical Almanac after adopting the ayanāṃśas according to the Grahalāghava. It shows the moon's conjunctions in R.A. with the following eight stars occurring before she enters the 'diurnal divisional nakṣatras' of those names :—Ārdrā, Āśleṣā, Jyeṣṭhā, Mūla, P. Āṣāḍhā, U. Āṣāḍhā, Śravaṇa and Dhaniṣṭhā. Similarly, if these conjunctions of the moon with stars be compared with those given in Keropant's almanac it will be seen that according to Keropant's almanac, the moon and also every planet is conjoined with the stars U. Āṣāḍhā Śravaṇa and Dhaniṣṭhā before its entry into the corresponding diurnal nakṣatra division, while in the case of Punarvasu, Puṣya, P. Phalgunī and Śatatārakā the same phenomenon occurs after its entry into the daily nakṣatra divisions. In short, one may adopt an accurate measure for the nirayaṇa system, but this dissociation of the stars from their nakṣatras is bound to persist.

Caitrādi Terms not Associative

Let us now consider the case of months. It is true that if the system on sāyana months be adopted, the definition* that the month in which the moon becomes full near the star Citrā is to be named Caitra, will not be found to be invalidated. But what is the actual condition these days ? At least a period equal to the antiquity of the Vedāṅga Jyotiṣa *viz.* about 3300 years has elapsed, since the system of naming the lunar month according to the proximity of the full moon to same star, was discarded. It is not known how long before that it had gone out of use. It is a fact that the terms Caitra, Vaiśākha, etc. originated in accordance to that rule ; but when it was noticed that the moon does not necessarily become full near the star Citrā in Caitra, two or sometimes even three stars were allotted in the case of certain months. But as the junction stars are not situated at equal distances, the system of

* On the full moon day in the month of sāyana Caitra, the moon will be definitely found to be in the (divisional) sāyana Citrā or in the nakṣatra, before or in advance of it.

divisional nakṣatras had to be adopted. The Vedāṅga Jyotiṣa shows a system of accurate divisional nakṣatra system. The system of accurate divisional nakṣatras came into use from the period in which the present siddhānta works on astronomy were compiled and the definition "*viz.*, that lunar month in which the sun enters Meṣa is called Caitra" came into existence and is now followed.*

The table on page 312** gives the nakṣatras in which the moon became full during the 4 years from Śaka 1804 onwards and in Śaka 1810 in the Keropant's almanac.

This will show that anyone out of three nakṣatras was occupied by the moon on each full moon day; and a still more striking case is presented by Aśvinī and Maghā in 1804, since in these months the nakṣatras on the fuls moon days were Uttara Bhādrapadā and Puṣya respectively. If month are to be named after the nakṣatras those months ought to have been called Bhādrapada and Pauṣa respectively; and because on the full moon day in the Āṣāḍhā of Śaka 1810, the diurnal nakṣatra was Śravaṇa, the month should have been called Śrāvaṇa. The same plight occurs in the case of the Grahalāghava almanacs. In short, if the principle of naming months after nakṣatras were to be followed, a good many (month) names would go wrong, no matter what accurate nirayaṇa system, we adopt. Hence the astronomers had no other course but to discard the system of naming the months accroding to the nakṣatra in which the moon became full.

According to the opinion of astronomers, the terms Caitra, Vaisākha, etct. are conventional and not associative; but even Pāṇini and the compilers of Smṛtis hold the view that they are not associative. The author of Kālatatvaviveka observes as follows about it :—

चैत्रादयः स्वतंत्रा एव रूढा राजवत् ।...... चैत्रादिशब्दा...........न नक्षत्रयोगनिमित्ताः । व्याकरणस्मृतिस्तु विपर्ययप्रतिपादिका स्वराद्यर्था । तदुक्तं वार्तिके 'यत्रार्थस्य विसंवादः प्रत्यक्षेणोपलभ्यते । स्वरसंस्कारमात्रार्था तत्र व्याकरणस्मृतिरिति । पाणिनिरपि सास्मिन्पौर्णमसीति संज्ञायामिति चैत्रादिशब्दानां संज्ञात्वं वदन् योगस्यापारमार्थिकत्वं दर्शयति । स्पष्टं च योगव्यभिचारे योगः प्रत्याख्यातः । ......विष्णुरपि नक्षत्रयोगनिमित्तत्वासंभवं पौर्णमासीनां द्योतयति......तथा च तत्स्मरणं......पौषीचेतa पुष्पयुक्ता...... ॥

Hence, it is needless to consider the objection that such terms as Caitr Vaiśākha, etc. would lose their significance by following the sāyana system for the objection can be raised with equal force, both against the Sāyana and Nirayaṇa systems.

Compromise

As regards the nakṣatras, if the nirayaṇa system advocated in our Siddhānta-works be followed, not only will the seasons go wrong, but there will be disorder about the nakṣatras also in the same manner as by the adoption of the

* A more detailed explanation has been given (page 270) before, while discussing the names of months.

** Of these years, according to that almanac the months, Caitra, Srâvaṇa and Āṣādha are intercalary in the Saka years 1805, 1807 and 1810 respectively.

MONTHS	FULL MOON'S NAKṢATRAS				
	Śaka 1804	1805	1806	1807	1810
Caitra	Citrā	Svātī	Citrā	Hasta	Hasta
Vaiśākha	Viśākhā	Anurādhā	Viśākhā	Viśākhā	Svātī
Jyaiṣṭha	Jyeṣṭhā	Mūla	Mūla	Jyeṣṭhā	Anurādhā
Āṣāḍha	P. Āṣāḍhā	U. Āṣāḍhā	U. Āṣāḍhā	P. Āṣāḍhā	Śravaṇa
Śrāvaṇa	Śrāvaṇa	Śatatārakā	Dhaniṣṭhā	Śatatārakā	Śatatārakā
Bhādrapada	Śatatārakā	U. Bhādra	P. Bhādra	U. Bhādra	U. Bhādra
Āśvina	U. Bhādra	Aśvinī	Revatī	Aśvinī	Aśvinī
Kārtika	Bharaṇī	Kṛittkā	Bharaṇī	Rohiṇī	Kṛttikā
Mārgaśirṣa	Rohiṇī	Mṛga	Rohiṇī	Ārdrā	Ārdrā
Pauṣa	Ārdrā	Puṣya	Punarvasu	Puṣya	Puṣya
Māgha	Puṣya	Maghā	Āśleṣā	Maghā	Maghā
Phālguna	P. Phalguni	U. Phalgunī	P. Phalguni	Hasta	U. Phalgunī

sāyana system, with the only difference, that it will take place in the reverse order and at a slower pace.* The months also will consequently be affected in the same manner. Even if the most accurate nirayaṇa measure be adopted the nakṣatras and months will be liable to the same error. It is true that the error will be always constant, nevertheless it is bound to persist. Hence it seems desirable to ignore the correct positions of the stellar nakṣatras, if the choice lies between seasons and the stellar nakṣatras. When we ignore the stellar nakṣatras we shall cease to name the lunar months after them and we shall begin to state the positions of planets with reference to new divisions called the sāyana nakṣatras ; that is, all the conjunctions of planets can be observed and their moments can be calculated ; similarly, the times of the conjunctions of planets with the nakṣatras (stars) can be calculated and noted in the almanacs.

If any one would argue that there will be a difficulty** in calculation through the sāyana system, the answer is that such is not the experience. The whole calculation in European astronomy these days is done on sāyana basis. Keropant maintains that (page 301) " because, the Sun, the Moon, the Planets and the Equinoxes all have motion, their positions should be measured only with respect to the Stars which are stationary ". This means that it is proper and necessary to take the help of fixed stars while taking observations; but in the compilation of the almanac, there can be no objection mathematical or otherwise against adopting the sāyana system. European astronomers do make use of the stars for observation, but all their calculations for the Nautical and other almanacs are made on the sāyana basis. Keropant has himself adopted sāyana positions and motions of planets for his book of PLANETARY TABLES and the planetary places calculated from it are all sāyana. Moreover, the method of taking observations by the "nalika" and the description of other instruments of observation, as given in our astronomical works (See chapter headed " systems of observation "), show that more use has been made of the sāyana measures than of stars.

More Doubts Resolved

रोहिण्यामग्निमादधीत ॥
न पूर्वयोः फल्गुन्योरग्निमादधीत ॥
पुनर्वस्वोरग्निमादधीत ॥
कृत्तिकाभ्य:स्वाहा ॥ ... रोहिण्यै स्वाहा ॥ ... स्वाहा पुनर्वसुभ्यां ॥
रेवत्यामरवंत ॥ अ चयुजोरयुंजत ॥ अ भरण ष्वपावहन् ॥

" A fire should be consecrated on Rohinī. It should not be consecrated on Pūrva Phalguni, nor on Punarvasu. 'Svāhā ' to Kṛttikā——to Rohiṇī ——to Punarvasu—— ".

* If the sāyana measure be adopted, the sāyana Aśvinī will be found contacting the stars Revatī, Uttara Bhādrapadā and so on in a regressive order, every 1000 years; and if the measures of the S.S. and others are followed, it will progressively cross the stars Bharaṇī, Kṛttikās and so on after every 6000 years.

** The author of the Pīyuṣādhāra commentary has attempted to show that a certain eclipse predicted by nirayaṇa system; was not predictable by the sāyana system. But if he had used the sāyana system in the correct way he would not have been assailed by any doubt (page 148).

These lines* contain the names of nakṣatras in the singular, dual, and in plural. This clearly shows that these nakṣatras are nothing but stars and verily these lines cannot apply to the sāyana nakṣatras, which shows that the Śrutis recognize only the stellar nakṣatras. And nakṣatras in that sense will not be obtainable by adopting the sāyana system. All the same, the fact remains that it would not be possible by the nirayaṇa system to secure the occurrence of spring in the months of Madhu-Mādhava, that is, in Caitra and Vaiśākha, for all times to come, and such occurrence too is a point stressed by the Śrutis.

The works on ritual facts prescribe the performance of particular rites on particular nakṣatras. If it be said that these nakṣatras refer to stars, practically no one has the faintest notion of such a fact. The nakṣatras are now observed simply as a matter of convention. Now-a-days the people are as a rule, satisfied if they find that the almanac gives the appropriate nakṣatra (division) necessary for a particular rite for the desired time, without caring to know which star is actually contacted (by the moon) in the heavens at that time. It is not that this condition is prevailing only in the present times. As the stars are not situated at equal distances, the condition is simply inevitable. The calculation for finding the accurate nakṣatra has been explained (page 279) : but no one makes practical use of it these days.** Even if it is done and even if the most accurate nirayaṇa system be adopted, it is impossible to secure the correct positions in every way. In addition to this, possibility of error in the calculatior is another obstacle in the matter. Even if we assume that the necessary correctness can be ensured, the ritualistic rules that enjoin the performance of particular rites on particular seasons cannot be observed by adopting the nirayaṇa system.

Pros and Cons Weighed

The nirayaṇa system cannot ensure the correctness of time for the performance of certain rites which must be performed according to the Dharmaśāstra in certain months and certain seasons, nor does it ensure the regular recurrence of Spring in the months of Madhu-Mādhav, that is, Caitra-Vaiśākha, which is a fact recognized by Śrutis as important. Will a system of astronomy be acceptable if (like the nirayaṇa system) it brings the rainy season in Caitra? Not one in hundred would answer this question in the affirmative, and to add to this, the nakṣatras too fall out of their proper places if one adopts the nirayaṇa system. These four arguments are favourable to the adoption of the sāyana system. The followers of nirayaṇa system will in their turn put forward four similar arguments that even the stellar nakṣatras are recognized by Śrutis and accordingly the Dharmaśāstra has laid down rules for performing certain rites under the rule of certain nakṣatras and these rules cannot always be observed if the sāyana system be followed. The stars of Revatī, Uttara-Bhādrapadā or those of all other nakṣatras will have to be called Aśvinī by turns by following the sāyana System, and no one would agree that it is proper :

* Most of the lines have been cited in Part I. But some more have been taken from the Taittirīya Śruti.

** Vasudeva Shastri Dedgaonkar, an astronomer of Poona, recently told the author that a certain Joshi of Paithan, some years ago, who found by calculation that a desired nakṣatra was available at a certain time got a marriage ceremony performed. But far from appreciating this welcome innovation, the local as well as the Poona public excommunicated him for sometime.

and although it is generally true that Spring would occur in Caitra for all time if sāyana system be adopted, the day of the beginning of seasons would shift a few days on either side ; and further, as the seasons are reckoned on the basis of lunar months, a variation of even a month sometimes occurs in the beginning of a season. Even granting these contentions of the nirayaṇa school and balancing one set of arguments against the other one cannot deny that there still remain two arguments advanced while discussing the logical aspect of this question, which establish the acceptability of the sāyana system (page 298/299). They are that the year is naturally a time unit defined by the cyclic recurrence of the seasons, and that the object of inserting an intercalary month is nothing else but to ensure for all time the concurrence of particular seasons and particular lunar months. Both these objects can be attained only by adopting the sāyana system. These two arguments are quite irrefutable.

Conclusion

Similarly, if the historical aspect of the question be considered, one finds that the sāyana year was in vogue from the earliest times till about 2000 B.S. Thus it is a fully and firmly established fact that ***the sāyana system alone deserves acceptance.***

Complete Revolution of the Equinox

We have considered the sāyana and nirayaṇa systems on the assumption that the equinox makes a complete revolution. The question of the Calendar reform has to be considered chiefly with a view to seeing that the almanac is compiled in conformity with the tenets of Dharmaśāstra. It may be argued that our works on astronomy assume that the equinox does not make a complete revolution but that it oscillates; and, if that be a fact, then the dissociation of seasons from months will not occur even by following the nirayaṇa system, and that, therefore, Spring will always occur in Caitra. Let us then consider this line of argument.

Whether the equinox makes a complete revolution or not, is not a matter coming within the purview of the Dharmaśāstra. The only concern of the Dharmaśāstra* is to decide what rites ought or ought not to be performed during the rule of certain seasons, months, tithis, nakṣatras etc; and it is for astronomy to decide what time conforms with the rules of the Dharmaśāstra. If the Dharmaśāstra enjoins that certain rites are to be performed in a certain month and certain season, then it is the duty of astronomy to establish such a system of time-measures as will ensure the association of the seasons with the appropriate months. The science of astronomy is based on actual facts. Because the positions and motions of planets undergo a change in course of time, it has become customary with astronomy to adopt such positions and motions as are confirmed by experience at different times. The modern Sūrya-Siddhānta gives positions and motions of planets that are somewhat different from those in the earlier Siddhāntas. Nevertheless the author observes that apart from the change in planetary motions necessitated by the lapse of time the ancient science has remained intact, as may be gathered from the following line in Madhyamādhikāra.

* The rules prescribing certain times for certain rites are given in the 'Muhūrta' branch of astronomy. The Muhūrtaskandha in this way forms part of the Dharmaśāstra.

शास्त्रमाद्यं तदेवेदं यत्पूर्वं प्राह भास्करः । युगानां परिवर्तेन कालभेदोऽत्र केवलं ॥ १

मध्यमाधिकार

" This is the same science which was deliberated by the god Sun. The only variation in time is due to the passing of long periods called ' Yugas'. "

Ranganath in his commentary on the above says,

कालवशेन ग्रहचारे किंचिद्वैलक्षण्यं भवतीति तत्तदन्तरं ग्रहचारे प्रसाध्य तत्तत्काल स्थितलो-
कव्यवहारार्थं शास्त्रांतरमिव कृपालुः [भास्करः] उक्तवान् ॥

" That kind Bhāskarācārya cited another science for the use of people, because planetary positions change with lapse of time. "

Bhāskarācārya says :—

अत्र गणितस्कंधे उपपत्तिमानेवागमः प्रमाणं ॥

गोलबंधाधिकार

Keshava also has made a similar remark (page 128).

Even the following well-known verse from the Vasiṣṭha Saṃhitā recommends the adoption of that system which will ensure agreement between calculation and observation.

यस्मिन् देशे यत्र काले येन दृग्गणितैक्यकं
दृश्यते तेन पक्षेण कुर्यात तिथ्यादिनिर्णयं ॥

"If the almanac in vogue in a territory, at any time, follows a certain pakṣa and its calculation agrees with observed facts, that pakṣa should be accepted and the decision regarding tithi etc. should be taken accordingly".

By observing the rules governing the construction of the Universe, the western astronomers have established with certainty the fact that the equinox makes a complete revolution.*

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*The author gives in brief an idea of the revolution of the equinox. Think of a children's top spinning on the ground. At first it revolves very rapidly in an upright position so that its axis passing through the two ends remains perpendicular to the ground. As its speed diminishes, it begins to nod because its upper part is heavy and in that condition its axis no longer remains in a vertical position and its upper end begins to revolve. In the same way, the extremities of the earth's axis continually begin to revolve round the end of a line perpendicular to the plane of the orbit of the Polar Star that is round the pole of the ecliptic. When the earth rotates round its axis, the axis does not remain in a position perpendicular to the plane of its orbit. Its speed of rotation round its axis is always uniform; it is practically constant. Hence, had it been completely spherical, its axis would have tended to remain inclined at the same angle. But the earth is flat at the poles and bulging at the equator. Hence, the attraction of the sun and moon on the equatorial part, shows a tendency to merge with the plane of its orbit. But the rotation of the end of the axis continues incessantly. This makes it impossible for the two planes to merge and for the axis to become perpendicular to the (plane of the) orbit. The axis of the earth, however, keeps revolving round the axis of the ecliptic. The poles of the equator revolve round those of the ecliptic. This causes the (celestial) equator to slide on the ecliptic. This is known as the phenomenon of the precession of the equinoxes. That the attraction of the sun and the moon on the earth is greater at the equator is noticeable by minute observation. The nodes of the moon's orbit make a revolution in 18½ years. This causes the moon to go away from the equator, sometimes to 28° north and sometimes upto 18° during that period. This and also her variable attraction on the bulging portion of the euqator causes a variation in the revolutionary motion of the pole. This variation is found to be the same after each period of 18½ years. The condition of the equatorial part of the earth being more bulging than that at the poles is not likely to change at least for millions of years more. Hence, the equinox is bound to make a complete revolution.

Even in our country Muñjāla and others hold the same view. A quotation from the Śatapatha Brāhmaṇa describing the position of the Kṛttikās has been given before (on page 128 of pt. I), which shows that it applied to a period about 3100 years before Śaka. The equinox has moved through 68° during the period of 4900 years from that date up to the present time, that is, through more than 54° which is supposed to be the arc of equinoctial Oscillation. Thus, even our own ancient works lend a support to the fact that thee quinox does not oscillate but makes a complete revolution. This being so, our Dharmaśāstra ought to abide by this verdict of astronomy and accept the sāyana system which ensures the association of seasons with months and our astronomers must compile their almanac only by that system.

Successive Regression of Year-beginning by One Month, as Solution of Problem

Some people suggest a different solution in order to maintain the Nirayaṇa system and at the same time to avoid the difficulty that will arise in future in being compelled to perform religious rites in the wrong seasons, owing to the present day nirayaṇa system. It is this :—instead of the sāyana year the correct nirayaṇa year-measure should be adopted ; the nakṣatras, rāśis, and saṃkrāntis too should be nirayaṇa. The present system of naming that lunar month as Caitra in which the Meṣa Saṃkramaṇa occurs should also be retained. But when the ayanāṃśa amounts to 30°, and the equinox moves back to the beginning of the nirayaṇa Mīna rāśi, the year should be made to start at the beginning of nirayaṇa Mīna, in the nirayaṇa Phālguna (of the present day), and the names of Madhu-Mādhava which denote seasons and are now applied from Caitra should.be applied from Phālguna, and all religious rites which are to be performed in Caitra, Vaiśākha etc. should be performed in Phālguna, Caitra etc. ; that is to say all religious functions should be regressed by a month. When after a lapse of time the advent of Spring begins to coincide with Māgha, the rites pertaining to Caitra and Spring should be shifted back to Māgha, This arrangement would ensure the performance of religious rites, usually observed in Caitra (Spring) to be performed in Phālguna and Māgha but still in Spring. There will no more be any necessity to call the divisions occupied by the stars Revatī, U. Bhādrapadā etc. as Aśvinī. This was the opinion of Keropant Chhatre and Krishna Shastri Godbole and the same view is now held by Prof. Tilak and Venkatesh Bapuji Ketkar.*

It is not Traditional

The suggestion appears desirable at the first sight ; but in reality it is not acceptable. Some of its advocates remark that there is even the support of tradition behind it. They observe that according to the Vedas, the year should begin on the winter solstice (W.S.) day and (it is also known) that the W.S. was gradually set back from Phālguna to Māgha, Pauṣa and Margaśirṣa. Keropant mainly relied upon the quotation "Yā vaiṣā ...." (quoted on page 30 of Pt. I) from the *Sāṃkhyāyana Brāhmaṇa* in this matter. Tilak has added one more month, Caitra, to the above list of names on the basis of the stanza from the Anuvāk of Samvatsara Satrā (given on page 28/29 of Pt. I).

I have already shown before (page 135 of Pt. I) that the Vedicq uotations cited as authority by Chhatre and Tilak, have nothing to do with the winter Solstice.

*Keropant's views had appeared in the *Arunodaya* newspaper in the issues of 7th October and 4th November 1883 and that of Ketkar was published in the same paper about 1884.Tilak's view is found in his book ORION but particularly in an article appearing in the *Kesari* sometime in 1893. Go dbole had expressed his views in a personal talk with the author. Bapudeva did not hold this view. His views have already been stated (page 301).

At no other place in the Vedas has the beginning of the year been shown to be with the W.S. This author is not alone in holding this view, who says so. Even Sāyanācārya has not interpreted these lines as bearing on the W. S. Similarly, Madhavācārya also has discussed this point in his *Kālmādhava* on the basis of several Vedic quotations and concluded that the year used to start at the beginning of Spring in Caitra. He did not come across a single statement in the Vedas, in which the year was said to begin on the W.S. He was also not led to draw the conclusion, that the year beginning was gradually made to recede through Caitra, Phālguna, Māgha and so on.

It is true that in the Vedāṅga Jyotiṣa the W.S. is mentioned as occurring in Māgha. The same system is found at one or two places even in the Mahabhārata. All astronomical works except Vedāṅga Jyotiṣa refer to the W.S. as occurring in Pauṣa but this does not prove that there was the practice of naming the months gradually backwards as Māgha, Pauṣa etc. It will be explained* how the W.S. occurring in Māgha during the Vedāṅga Jyotṣa period began to occur in Pauṣa. The advent of Spring used to occur in Caitra at the time when Caitra and other names of months came into use. Hence, the authorities on Dharmaśāstra applied the system of calling Caitra-Vaśākha the months of Spring season on the analogy of the "Madhu-Mādhava" names of the Vedic period and like the month of Madhu they adopted Caitra as the initial month of the year. Even though the W.S. used to occur in Māgha during the Vedāṅga Jyotiṣa period, it did not affect the system. But later on, because the solar ingress into Meṣa used to take place in Caitra when Meṣa and other terms became current and the year already used to begin in Caitra, astronomers formulated the rule "Meṣādhiṣthe Savitari ...." (page 270) for naming the months. This terminology was not at all current in the Vedānga Jyotisa period and hence the religious heads accepted the rules established by astronomers. On account of this, the Makara Saṇkramaṇa occurred in Pauṣa itself, the W.S. which formerly used to take place in Māgha had naturally shifted to Pauṣa and the convention of the W.S. and Makara Saṇkramaṇa occurring in Pauṣa became a rule and was acceptable to the authorities on the DHARMA ŚĀSTRA. It has already been pointed out in the course of the study of Vedāṇga Jyotiṣa that the Vedāṇga Jyotiṣa system was not everywhere in use in its original form for many years. Hence, because the rule of the W.S. occurring in Māgha did not last long universally, it was not difficult to establish the convention of linking up the W.S. with Pauṣa. Now the terminology cannot change for, though it is now-a-days sometimes seen that the W.S. occurs in Mārgaśīrṣa, still it is not recognized by the Dharmaśāstra, nor would it be acceptable. That it was not acceptable to the Sūrya-Siddhānta can be seen from some of its verses given above (page 300). Whatever is unacceptable to astronomy cannot be acceptable to the Dharmaśāstra also. In short, even though the W.S. sometimes now-a-days occurs in Mārgaśīrṣa, still, the fact is not recognised by the Dharmaśāstra ; and the tradition of shifting the beginning of the year back by a month every 2000 years is not found in the Dharmaśāstra. None of the works on the Dharmaśāstra will be found to give any of the two facts discussed above.

*If months are named on nirayaṇa basis, the W.S. is found to occur in Magha, Pauṣa Mārgaśīrṣa and so on, gradually in a backward order. But it is to be seen if it was the tradition to call that lunar month Phālguna, Māgha and Pauṣa, in which the W.S. occurred; in other words, I wish to discuss, if it was the tradition to begin the year one month earlier after every two thousand years, after naming the months on the nirayana basis : and it is being proved that there was no such tradition.

The stanzas (Anuvāk) describing year-long sacrifices speak of beginning the series of such sacrifices on the Citrā full moon day, the Phalgunī full moon day and the Ekāṣṭakā (8th lunar day of Māgha Kṛṣṇa) day. It shows that even if the W.S. and the beginning of the year ceased gradually to take place on those days, as years rolled on, still the occurrence of the beginning of Spring and that of the year must have coincided with those days. And if any one begins to argue on this basis that the tradition of setting back the beginning of the year gradually by one month can be discerned here, it would also be impossible because the Anuvāk relating to the yearly sacrifices occurs in the *Taittirīyā Saṃhitā* and the *Tāṇḍya Brāhmaṇa*. The dates of both the works are not later than 2000 or at the most 1500 B.S.; and this estimate must be acceptable to Tilak also. Hence, there was no possibility of Spring occurring in Māgha in those times (pages 131/132 of Pt. I). It has already been shown (pages 265) that the practice of beginning the year on the Ekāṣṭakā day must have come into vogue owing to some other reason and it must have had a secondary importance. Now the full moon days of Caitra and Phālguna remain to be considered. It is a well-known fact (of astronomy) that every solar ingress takes place within 29 days earlier or later than (the starting of) a lunar month. The solar ingress into Meṣa occurs on any day between the 1st lunar day of Caitra and the new moon day of that month; consequently, a similar variation takes place in the beginning of any season. Hence, Spring can be seen to begin, in some year on the Phālguna full moon day and sometimes on the Caitra full moon day during any particular period ; and according to the 'pūrṇimānta' system, the month ends on the full moon day. Hence at the time when exact rules for beginning the year were not established, it was naturally felt that the year could begin on either of the two tithis. Sāyanācārya has interpreted this stanza on these very lines. The work Kālanirṇaya by Mādhava supports this very interpretation*. Cases of starting the year in different months have been given before (pages 263/265) and it has been pointed out there that there was no such tradition of commencing the year one month earlier.

In short, there is no tradition in favour of setting the year back by month by the nirayaṇa system and it is not in conformity with the rules of the Dharmaśāstra ; hence, this adjustment is not acceptable to Dharmaśāstra.

NOT ACCEPTABLE TO PUBLIC

Setting the beginning of the year back by a month and performing rites in Phālguna which are meant to be performed in Caitra, is nothing but altering the Dharmaśāstric rules. So long as these views remain on paper, it is all right. The originators and followers of this view do not appear to have realized how ridiculous it would be in the eyes of the Śāstris and the general public. Muñjāla's views on the precession have been condemned as those of an atheist and a avan by Munishwar, the author of the commentary called Marīchī, (page 212), because, the theory that the equinox makes a complete revolution does not ensure the occurrence of seasons in a way acceptable to the

*When this book was first written in 1887 i.e., before Prof. Tilak's book was published the author had already considered the quotations (Anuvāk) relating to the beginning of the year, and he had already construed them in the way he has done here and on pages 135/136 of Pt. I then Prof. Thibaut's review of Tilak's book appeared in the monthly Journal, "Indian Ant iquary" in 1895, and he has there interpreted the quotations just as the author has done., This discussion includes also the consideration of arguments put forth by Keropant in support of his contention.

Śrutis (page 212). In his eyes even the verbal argument regarding the dissociation of the seasons and months appeared distasteful. How then can the authorities on the Dharmaśāstra like him tolerate actually performing those rites in Phālguna which really belong to the month of Caitra ?

EVEN THIS SOLUTION CAUSES ERROR IN SEASONS

If the year is made to begin at the first point of Mīna, when the equinox begins to occur in the initial point of the nirayaṇa Mīna sign, it will not be found to be there perpetually, because it will also continue to recede, as the equinox is always movable; and an error will continue to occur till the equinox would reach the initial point of Kumbha. Even if the year is then made to begin at the initial point of Kumbha, the error will still persist. In short, even by following this system, an error of up to 30 days will always continue to remain in the recurrence of seasons.

AN INSUPERABLE DIFFICULTY

There is yet another difficulty which cannot be tided over. Some religious rites are related to seasons, months and tithis. These may be transferred to a time a month earlier. But there are some which are connected with the seasons, months, tithis and also nakṣatras. For example, the Vijayādaśamī is to be observed on the tenth lunar day of the bright half of Āśvina in the Śarat-ṛitu. The association of Śravaṇa nakṣatra with it is desirable. This is not possible, on the 10th lunar day of Bhādrapada Śukla, as it would fall on the 12th lunar day of the bright half of that month and on the 14th lunar day of the bright half of Srāvaṇa. If Vijayādaśamī is celebrated in Bhādrapada, the Śravaṇa nakṣatra will not be available. If it is celebrated on Śravaṇa nakṣatra on the 12th lunar day, then Daśamī (10th day) will be missed. (In that event it will have to be called a 'bāṛas' and not the 'daśarā'). As time will pass, it will be made to recede into Śrāvaṇa, and then it will have to be performed on the Śravaṇa nakṣatra on the 14th tithi or on the 10th tithi associated with Jyeṣṭhā nakṣatra.

WHO CAN CHANGE THE DHARMASHASTRA ?

If, however, it be resolved to accept this solution inspite of its being contrary to the tenets of Dharmaśāstra, the Dharmaśāstra will have to be completely overhauled. Who is going to do that and how ? Such would be the difficulties confronting the reformers. He, who knows anything about the works on the Dharmaśāstra and popular beliefs, will realize that this is extremely difficult to achieve.

HOW TO POPULARIZE NEW DHARMAŚĀSTRA ? HOW TO MAKE IT CURRENT ?

If it be assumed that the Dharmaśāstra can be renovated by appointing a *Committee of Sāstrīs* how is the new Dharmasāstra to get recognition ? This is even more difficult than the above proposal. Even supposing that Śaṅkarācārya approved it or that it was passed into a law, one can hardly imagine how very difficult it would be to introduce it into the religious life of the people. Our country has hundreds and thousands of *Works on Dharma* and lakhs of their copies are in circulation all over the country ; all these will have to be destroyed. If they are repealed by a peremptory order there would still remain works on other subjects which cannot be destroyed. It is preposterous

to think of changing a system that still remains recorded in those thousands of works and is deeply engraven on the hearts of millions of people. The winter solstice which used to occur once in the beginning of Dhaniṣṭhā, later on shifted to Uttara Āṣāḍhā ; still, the Dhaniṣṭhādi system continued to exist in astronomical works. It is found in two or three works only and its use was confined only to a small area and that too for a very short period of time. Still even this resulted in deluding an astute astronomer like *Varāha Mihira.* If then a system, which at present has specific nakṣatras, months and seasons for specific religious rites and which found its way into thousands of works and has remained in vogue for quite a long period of time all over the country, be altered—that is to say, for instance, if the festival of 'Daśarā' occurring in Āśvina, be decided to be celebrated on the 12th lunar day of Bhādrapada—it will take scores of pages to describe what confusion will occur in the minds of the people at large and what troubles would arise among the ignorant section of the public.

SUGGESTION WORTH REJECTING

In short, all things considered, a system which involves the recession of the beginning of the year and other rites gradually from Caitra back to Phālguna, Māgha and other months deserves only to be rejected.

PRACTICAL ASPECT

Let us now consider the sāyana and nirayaṇa systems from the practical point of view. It is not that the everyday life will be obstructed in the absence of the sāyana system. We need not consider, of course, those people who do not require any almanac whatsoever in their daily life. Our discussion must then be confined only to those who do want some almanac or other. About Śaka 444, the rainy season used to begin when the sun had crossed about half the division of Ārdrā nakṣatra; now it starts at the beginning of Mṛga. At present, the 'jwari' which is the staple food of the people living in the region around Barsi and Sholapur, is sown when the solar nakṣatra of Hasta is about half passed. It is obvious that about Śaka 444 such sowing used to take place with the sun in the beginning of Svātī. But people do not even dream that there ever was a time when the sowing began during the Svātī nakṣatra. People feel as if the rule regarding the sowing of grains in Hasta has been in force right from the beginning of creation. If the nirayaṇa system continues in future, the sowing operation will have to be done in Uttarā, as time would pass on. But this variation is so slow that it will not be perceptible in the lifetime of any man or for that matter, even during three or four generations, and thus it would come about quite naturally without being detected in the least. In the same way almost all the affairs of life will continue unhampered even if the sāyana system does not come into vogue.

But marriage is a ceremony intimately connected with everyday affairs as well as Dharmaśāstra. It has been already pointed out (page 307) that the nirayaṇa system will cause a difficulty in regard to its celebration. It is true that it will occur after a considerable lapse of time; but that it will occur is a certainty. Even at present, the month of Jyaiṣtha, even though allowed for celebrating marriages, is in some years found to be useless because of the rains. Let us now see if, on the other hand, the acceptance of the sāyana system

would give rise to any difficulty in this matter. Our months are lunar and hence, intercalary months are required to be introduced. This fact is very favourable for the introduction of the sāyana system. In the time of *Julius Caesar* the length of the year was once required to be extended by some days. In the times of *Pope Gregory* and later in 1752 A.D. in England, an adjustment was required to be made by passing a law that the proper date of a certain day would be arbitrarily advanced by some 10 or 12 dates. People must have found it very awkward. The change was brought about only with the help of law. But we need not proceed that way. If an intercalary month that is due according to the old Pañcāṅga be omitted altogether and if the sāyana Pañcāṅga be introduced since that month and all intercalary months thereafter reckoned on the sāyana basis, our purpose will be accomplished; and if all the almanac makers make up their mind, the change will be effected most smoothly without embarrassing the people in the least. This is no doubt a great facility. Nevertheless, there is one thing that may still create confusion among the people. At present, the sāyana Ārdrā nakṣatra is ruling at the time when the nirayaṇa Mṛga nakṣatra begins, and then the rains set in. Hence, people will be wondering why the rains do not start even when the Ārdrā nakṣatra is half passed, though ordinarily they are due at the beginning of Mṛga. When the rainy season is about to begin people would perhaps start those agricultural operations at the beginning of the sāyaṇa Mṛga nakṣatra, which they used to begin at the beginning of the nirayaṇa Mṛga nakṣatra. Thus an obstacle will be created in our every day affairs. However, if the change is brought about gradually, it will not create difficulties in daily affairs. But setting back all saṃkrāntis and solar nakṣatras by 22 days would be a very difficult thing to do. If a change occurs in the dates of such phenomena, as Jupiter's change of sign or the sign occupied by the moon, people will not notice it. But people will find it rather awkward to take to sowing in Svātī which is usually done in Hasta. The ideas about nakṣatras and solar saṃkrāntis are so deep rooted in the minds of the people that any change with regard to them would seem more difficult to our people in their daily life than the advance of 10 or 12 dates seemed to the Europeans. If some people decide to adopt the sāyana almanac, it does not mean that all others will at once agree to adopt it; and in that case, as the nirayaṇa almanac will still remain in use, people will come to understand that the month which they call Phālguna will have to be called sāyana Caitra. The solar ingress of Brahmagupta, which used to occur one day earlier, had come into vogue; still, ultimately it fell into disuse. The solar ingresses of Keropant's almanacs occur four days earlier and this is one of the main reasons why his almanac has not come into general use. Hence, it will be very difficult to bring into use the sāyana almanac which shows solar ingresses as occurring *22* DAYS EARLIER. There are no doubt some such difficulties and it is proposed to consider later how they can be surmounted.

ASTROLOGICAL ASPECT

That the sāyana system is acceptable has been so far proved from the point of view of mathematical astronomy and muhūrta. Whatever is acceptable to these two must be acceptable to *Astrology* (*Jātaka Skandha*) also. It is true that the decision of this point will depend partly upon the question which of the two systems yields a *horoscope* (*or forecast*) that would be in conformity with actual experience Madhava Brahmaji and Jeevan Rao Tryam-

tak Chitnis*, both advocates of the sāyana system, declare that the *horoscope* cast by the sāyana system gives correct results. Again the well-known European astrologers of the present day, Zadkiel and Raphael, cast *horoscopes* only by the sāyana system. In our country the *horoscopes* are everywhere cast according to the nirayaṇa system. The JYOTIRNIBANDHA, however contains this quotation from the JĀTAKOTTAMA.

उच्चतः सप्तमं नीच प्रोक्तज्ञै परिनीचता ।

इह कार्यः सायनांशखचरेः फलनिर्णयः ॥

"The 'neech' is seventh from the 'Uccha'. The decision about 'phala' (result) should be taken on the basis of the sāyana positions of planets".

It shows that even our old writers held that the sāyana system was acceptable in the matter of ASTROLOGY. Most of the works on ASTROLOGY were compiled at a time when the initial points of the sāyana and nirayaṇa systems did not differ much. It may be for this reason that they appear to have been compiled on the sāyana basis. This point will be more fully discussed later in the JĀTAKA SKANDHA. The author has come across several people who say that they would be prepared to accept the sāyana system if the *horoscopes* cast on the sāyana basis would be proved to give correct results. But the author thinks that it is impossible to get completely correct results by either of the systems. Furthermore, the science of astronomy has not originated for the sake of *horoscopes* alone.

THE BEST AND MOST ACCEPTABLE SOLUTION

The logical aspect of the question considered at the outset would appeal to all people at all times and at all places. Hence, in the light of that consideration (1) *the best solution is to adopt the sāyana system.* It has already been shown above that from the point of view of History and Dharmaśāstra also, that solution alone is acceptable. This course may cause a slight hindrance in our every-day life in the beginning. But the hindrance due to setting back the beginning of the year by 22 days will be quite negligible compared with the difficulties and mental confusion experienced by people when in the year 46 B.C. Julius Caesar advanced the beginning of the year at one stroke by as many as 67 days at the time of reforming the Calendar. Moreover it has been explained above how the intercalary month would facilitate the change from the nirayaṇa system to the sāyana system. All that we have to do is to introduce the sāyana pañcāṅga from the year in which an intercalary month falls due according to the Grahalāghava but not according to the sāyana system. The tithis would be identical by both the systems. There would be some difficulty in respect of agricultural work for a few years. But if rules are given in the almanacs for some years to the effect that certain agricultural operations now performed under certain solar nakṣatras should in future be performed under other nakṣatras. And if this is put into use for some years it will continue for all time to come without any break or difficulty. It is, however, essential that an authoritative work should be first published from which the sāyana almanac can be compiled.

* Madhava Rao Brahmaji had published a book entitled *Samvatsar Bhavishyamala*, containing the forecast for Śaka 1806. The predictions in this book were made on the sāyana basis. Chitnis has been publishing *Jyotirmala*, a monthly journal at Bombay since May 1895. It deals with astrological questions on the sāyana basis.

ANOTHER SOLUTION

The above solution will cause no difficulty regarding the tithis and nakṣatras required for daily use. But some confusion will arise in the matter of agricultural work as the solar nakṣatras indicating the advent of rains etc. would be set back by 22 days. The stellar nakṣatras will create some mental confusion because they will show a divergence of about 1¾ nakṣatras. If, therefore, this course be considered as being set with too many difficulties, there is still an alternative to it which is explained below. The amount of ayanāṃśa derived from the Sūrya-Siddhānta and allied works for the present times (22° for Śaka 1805) should be regarded as constant for all time to come and the correct length of the tropical year should be adopted. This will reduce the precessional (ayana) motion to Zero. The difference of 22 days which affects the seasons at present will thereby remain constant. When a work is compiled for calculating the almanac in conformity with this solution no obstacle will come in the way of bringing the system into vogue. Neither royal mandate, nor the sanction from Śaṅkarācārya nor any other kind of help will be required. Just as the *Grahalāghava* came into extensive use even in the absence of the printing press, the astronomical work and the pañcāṅga compiled on these lines will easily come into universal use.

It has already been proved above that the nirayaṇa system is not at all worthy of acceptance; if, however, it be felt that it is impossible to make the sāyana system acceptable and that the nirayaṇa system must need be retained, let us consider whether any one of the three types of nirayaṇa almanacs, viz. the Grahalāghava type, the Keropanti type and those by Bāpudeva and others, should be accepted or an almanac of quite a different kind should be accepted. It has been shown above, while discussing the logical aspect of the question, what will be the effects of adopting the length of the sidereal year according to the Sūrya-Siddhānta and others. Hence, anyone will agree that this should be abandoned and the true sidereal year should be adopted. It is the view of Bāpudeva that the length of the year should be taken according to the Sūrya Siddhānta and the almanac should be compiled on the basis of the correct motions and positions of planets, and Raghunāthācārya too appears to hold the same view. The only object of this suggestion is that if the beginning of the year is reckoned according to the S.S. the difference in the ayanāṃśa does not become perceptible. Thereby the solar ingresses and the intercalary months will occur as before, and there will be no difficulty in making the almanac acceptable to the astronomers as well as the public. There does not appear to be any other object underlying the suggestion. But if there be a solution which accomplishes the above object and at the same time ensures the adoption of the correct length of the year, Bāpudeva and others will no doubt readily accept it. Keropant on his part holds that the correct sidereal year should be adopted; but he also holds that the star *Zeta Piscium* should be taken as the initial point. But that would result in the divergence of solar ingresses by 4 days and the intercalary months also would be different; and on account of this Keropant's almanac has not become popular. It is true that the star *Zeta Piscium* was near the first point of the Zodiac about Śaka 444; but the S.S. does not give zero as the longitude of the star Revatī: it is 359° 50′ that is 10 minutes less. *Lalla* has assumed 359° as the longitude of Revatī, which is one degree less. *Brahmagupta* and the later astronomers have assumed the longitude of Revatī to be zero. It has been, however, clearly

shown that neither *Zeta Piscium* nor any other star can for ever coincide with the first point of the Zodiac according to them or any other work (page 218). It is no doubt true that it was the intention of *Brahmagupta* and later authors that *Zeta Piscium* should be taken to be at the initial point. The asterism of Revatī contains 32 stars. If a star be found in this group whose distance from the equinox of this date be almost equal to the ayanāṃśa of the present day, as derived from different works and if *Brahmagupta* and all other astronomers were living to-day, they would gladly have agreed to accept the star as the initial point and to adopt the correct sidereal year. *Keropant* does not appear to have read the history of the shifting of equinoxes as recorded by all our astronomical works. While introducing his almanac he did not take care to see if the almanac would be acceptable to the public, when the time of the sun's ingress was set back, because of the adoption of a smaller figure for ayanāṃśa; and there was no reason why that idea should have struck him at that time. It, therefore, seems that he did not try to see if there can be a solution by which even if the correct length for the nirayaṇa year be adopted, the change would not be perceptible to the general public. It is found that there is such a solution. The star group of Revatī has been described by our works as forming a Mṛdaṅga (tabor). It includes a star whose distance from the equinox in the beginning of Śaka 1809 is 21° 32′ 57″. It is much nearer to the initial point of our Śiddhāntas than the star Zeta Piscium. It has already been given in a table (page 292), the figures representing ayanāṃśa according to different works derived on the basis of the length of the year adopted by them. They vary from 21° 56′ to 22° 3′. If the mean sun be taken into account they will be found to vary from 22° 4′ to 22° 18′. It has also been pointed out above (page 291), that looking to the current practice in our country, the ayanāṃśa adopted at one place in Śaka 1809 is 22° 45′, at another place it is 22° 44′ and it is 20° 49′ at still another place. Hence, if the above mentioned star be accepted as the initial point, the ayanāṃśa for Śaka 1809 will be 21° 33′. This amount is very near to all those mentioned above. This (star) is as useful for observation or for mere gazing as Zeta Piscium so far as luminosity is concerned. Another facility offered by this star is that while 11 stars will be found misplaced if Zeta Piscium is taken as the initial point, only seven* will come to be misplaced if this star is substituted. Hence, this star should be adopted as the initial point and its distance from equinox adopted as ayanāṃśa or else the star *Spica* is very useful for observation. The S.S. gives 180° as its longitude. It is surmised that ancient astronomers might be determining the positions and motions of planets after comparing their observed co-ordinates with this star. Hence, supposing the longitude of *Spica* to be 180°, the point at a distance of 180°, should be taken as the initial point. As the sāyana longitude of Spica in Śaka 1809 is 6 signs, 22° 16′, the ayanāṃśa for Śaka 1809 would be 22° 16′. This figure also is very near to all the values mentioned above. If the initial point be adopted in the light of this discussion only seven or eight stars will be found misplaced. In short, the ayanāṃśa for Śaka 1809 should be assumed to be either 21° 33′ or 21° 16′**. The ayana motion should be adopted at its true value $50\frac{2}{10}$ seconds and the

* The accurate longitudes (according to Keropant) of junction stars which have been given on page 308/309 are their distances from Zeta Piscium. This star is about 3° 15′ ahead of Zeta. By adopting this star as the initial point, all those stars, except Uttarā Bhādrapadā, before which the word 'in advance' is written will be found to be in their respective 'regions'. Only seven will be found misplaced and of them Jyeṣṭhā will fall behind by only 2 minutes.

** This part of the book was first written in Śaka 1810. Hence all calculation has been made for Śaka 1809.

year-measure should be the correct length of the sidereal year, that is, 365*d*-15*gh*-22*p*-53*vp*.

THIRD SOLUTION

This solution is the best of all those exemplified by all the current almanacs, and if the above two ways of adopting it, as also those of Keropant, Bāpudeva and Raghunāthācārya, and the sāyana system be not acceptable, then it is better that this third one be followed. If it is followed there will be a variation of only a few ghaṭis in the occurrence of the solar ingresses, and there will be agreement in the case of almost all the intercalary months and there will be practically no difference. It is, therefore, sure that this second solution will be welcomed and when a new Sanskrit work following this system and tables simplifying the calculation of tithis on the lines of the *Tithi Cintāmaṇi* are compiled, the system will very quickly gain currency. Had any one suggested this solution to Keropant he would have accepted it readily. This method differs from the one he has adopted for the Patwardhan almanac only in this respect that another star will be substituted for Zeta Piscium as the starting point. As the object of Bāpudeva and Raghunāthācārya would be fulfilled in this way, even their followers would approve of the proposed method.

The second and third solutions mentioned above differ from the old almanacs only in point of length of the year and the adoption of correct motions and positions of planets. If an almanac compiled on these lines is given to any sensible person, he will perceive in it nothing unacceptable or different from the old ways. In short there can be no objection whatsoever to bringing into practical use any of the two solutions..

NEW WORK NECESSARY

The discussion about the three solutions and the discrepancies already shown (Page 295) as occurring in the planets' places as calculated from the Grahalāghava, clearly show that there is the need of a new work being compiled which will give the correct positions and motions of planets. The Planetary Tables compiled by Keropant is a work which gives tolerably accurate positions and motions of planets, if not quite as accurate as those given by the *English Nautical Almanac*. But because it has adopted the length of the year as in the S.S. and the planetary positions are sāyana, the work is absolutely of no direct use to the followers of any of the three systems. It will, however, prove helpful to any one in compiling a new work. The new work should be compiled on the basis of those works which have proved helpful in compiling the *English or French Nautical Almanac*. Considerable difficulty will be experienced in using them, since those works are written in French, the planets' places obtained from them are sāyana and the system of calculating the length of the year is also different from that of ours. It is, however, possible to compile one in metrical form and in Sanskrit. It should contain mathematical tables to help calculating planets' places from them, with as much or even less pains than those required with the *Grahalāghava*. In addition to this it is necessary to have tables on the lines of the Tithi Cintāmaṇi by Ganeśa Daivajña to facilitate the calculation of the ending moments of tithis, nakṣatras and yogas in ghaṭis and palas. It is also possible to prepare them. When these two works are prepared, the task of bringing into use any one of the three, especially one of the last two systems into use, will be considerably facilitated. It is informed that Venkatesh Bapuji

Ketkar has compiled a work with the help of which an almanac like the one by Keropant could be compiled. But that work has adopted ayanāṃśa from Zeta Piscium and hence it appears difficult to introduce it for everyday use. *Babaji Vitthal Kulkarni** has compiled a work similar to the Grahalāghava ; but it is told that he has adopted in it the length of the year according to the S.S. and the planets' places obtained from it are sāyana. Hence, it is of no use to any of the systems and unlikely to gain currency. Neither *Bāpudeva* nor any of his disciples is known to have compiled such a work. Raghunāthācārya has compiled a work (page 182), but it is not known, what year-measure has been adopted by it, and if any almanac, following any of the three methods described above, could be compiled from it. In short, a work of the desired type is not at present available. The author desires to compile one and is trying with that end in view. He hopes that his endeavours will be crowned with success by the grace of God.

(3) THE ADHIKĀRA ON THREE PROBLEMS

The Adhikāra on three problems is so called in our astronomical works because it deals with the questions of direction, region and time. The method of determining directions is given in it in different ways. It is explained how to find the ascendant for a given moment or conversely the unknown moment from the given ascendant. The calculation by other methods is also possible, *e.g.* four shadows, etc. The question of 'deśāntara' (longitude) from *Ujjain* is usually dealt with in the chapter on mean motions and therefore omitted in this chapter. It, however, contains methods for finding the distance of a place from the equator, that is, latitude. The question of shadow is dealt with at considerable length. For calculation, a gnomon 12 'aṅgulas' long, is taken as the unit while determining the length of the shadow. What will be the length of the shadow cast by a gnomon at a given moment and in what direction it would fall, and what would be the length and direction of the shadow cast by the Sun (or a planet) posited on any side of the gnomon, and such other questions are included under "determination of shadow". The authors preceding *Bhāskarācārya* have given only the method of calculating the shadow cast by the gnomon in an East-West, North-South, and the (four) intermediate directions. Bhāskarācārya alone has described the method of finding the shadow cast by the gnomon when the sun stands in any direction with regard to it. And on this point he proudly remarks :

Sanskrit

याम्योदक्समकोणभाः किल कृताः पूर्वैः पृथक्साधनै-
र्यास्ताहिग्विवरांतरांतरगता याः प्रच्छकेच्छावशात् ॥
ता एकानयनेन चानयति यो मन्ये तमन्यं भुवि
ज्योतिर्विद्वदनारविंदमुकुलप्रौल्लासने भास्करं ॥ ४४ ॥

सिद्धांतशिरोमणि, त्रिप्रश्नाधिकार.

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*Kulkarni has compiled works entitled Karaṇa Śiromaṇi and Graha Jyotsnā. I have not seen them and hence more information about them cannot be given. These works are not printed. I understand that Keropant Nana had a high opinion about these works. Kulkarni was born in Malvan in Śaka 1767 and died in Śaka 1815. He was in service in the Education Department in Ratnagiri District from 1865 to 1875 AD., and, later on in the Revenue Department till the end. He had also written a book showing the positions of stars which was printed in 1886 A.D.

Time is determined from (the length and direction of) shadow cast by the gnomon. The shadow is, however, mainly useful in setting up the 'Nalikā' sighting tube before observation. Following is the main method of setting up the 'Nalikā' for observation :—To determine, beforehand, by calculation from the astronomical works the length and direction of the shadow likely to be cast by the gnomon when set up in the light of the sun or any planet at a particular moment and then to set the sighting tube in that position for observing the planet. If the planet be observed in that position, then the position calculated from the book would be considered correct.

Palabhā is the name given to the length of the shadow cast by the twelve-aṅgula gnomon at any place on the equinoctial day. Palabhā forms the base, gnomon the perpendicular and the line joining the extremities of the gnomon and the shadow, the 'akṣa-karṇa' (hypotenuse). The area bounded by this right angled triangle is termed '*akṣa-kṣetra*'. This region of 'akṣa-kṣetra' has much importance in our astronomy. At many places, the measures of different items are calculated by drawing another figure similar to this 'akṣa-kṣetra'; and the Adhikāra on three problems devotes much space to problems associated with such figures.

A list of latitudes and longitudes of some cities given in the *Siddhānta-Tatva-Viveka* has been given (page 163)

Malayendu Suri, a commentator of the *Yantrarāja*, has given latitudes of 75 cities. The work has been printed and the latitudes are of some cities that have been engraved on the instrument devised by *Sakharam* Joshi*, referred to before (in the footnote on page 233) :—

City	°	′	City	°	′	City	°	
Srirangapattan	15	27	Janasthan (Nasik)	20	12	Mathura	26	36
Bijapur	16	42	Bradhnapur (Burhanpur)	21	0	Madava	27	0
Karavir	17	21	Ujjain	22	37	Indra-Prastha	28	40
Saptarsi (Satara)	17	42	Ahmedabad	23	0	Kuruksetra	30	0
Nandigram	18	26	Varanasi	25	36	Kashmir	35	0

Lists like the above are now of no use, since the British Government has determined very accurate latitudes and longitudes of thousands of places in this country. It will, however, be seen that our people had made efforts in that direction and one can also judge how accurate it was.

*There is a commentary on the *Pratod Yantra* by Sakharam, wherein latitude 17° 41′ 50″ has been taken for working out examples. And Sakharam Joshi of Kodoli has also given 17° 41′ 50″ as the latitude of Satara. A copy of the commentary was obtained at Ashta in the Satara District. This indicates that the commentary definitely belongs to him.

(4), (5) ADHIKĀRAS ON ECLIPSES OF THE SUN AND THE MOON

That the cause of the lunar and solar eclipses is not the demon Rāhu, but the earth's shadow in the case of the lunar eclipse and the moon in the case of the solar eclipse, was known since the times of *Varāhamihira* and *Āryabhaṭa* who are the oldest known 'human' authors of astronomical works. While declaring that he would describe the cause of the eclipses in such a way as would reconcile the teachings of the Śrutis, Smṛtis and Jyotiṣa Saṃhitā with the astronomical theory, *Brahmagupta** observes "Rāhu entering the earth's shadow envelops the moon in the lunar eclipse, and entering the Moon, it envelops the Sun at the time of the solar eclipse", and *Bhāskarācārya*** also has explained the phenomena in the same way.

PARALLAXES

The parallax of the moon has to be taken into consideration in the case of the solar eclipse. Our works regard the maximum value of parallax as equal to 1/15 of the planet's motion ; which means that the maximum mean parallax of the moon is 52′ 42″ and that of the sun is 3′56″ ; compared with the findings of modern astronomy there is only a slight error in the value of the moon's parallax ; but that of the sun is very much mistaken. Modern discoveries show that the maximum value of the equatorial horizontal parallax is 57′ 1″ for the moon and 8.6″ for the sun.

Hipparchus has determined† 57′ as the moon's parallax and 3′ as that of the sun, while *Ptolemy* had found it to be 58′ 14″ for the moon and 2′51″ for the sun. It shows that our people have not taken these values from either.

Owing to the brilliance of the sun, the eclipse is not visible even if the twelfth part is eclipsed ; whereas in the case of the moon, the eclipse is visible even if the sixteenth part of the lunar orb is eclipsed ; Bhāskarācārya has remarked that an eclipse should not be declared if its calculated magnitude comes to be less than this. Almost all other writers have similarly observed that the eclipse becomes invisible, more or less within the same limits of observation. But on 19th August 1887, there was a solar eclipse and the magnitude of the eclipse was 7/100 at Gwalior, *i.e.* equal to about the fourteenth part of the solar orb. It was seen by Visaji Raghunath Lele with naked eyes, as also through a glass smeared with lamp-black and it was seen quite clear. He, however, found that it was very risky to see such a small eclipse with the naked eye, for the eye-sight is likely to be very much impaired.

(6) ADHIKĀRA ON SHADOW

Some Karaṇa works do not give a separate adhikāra to this subject. The *Grahalāghava* has given it separately. The chapter usually deals with the calculation of daily rises and sets of all planets (except the sun), the time of their remaining above the horizon *i.e.* length of their diurnal arcs, the length of shadow at any desired moment, observation etc.

*See couplets 34-48, Golādhyāya in Brahma Siddhānta.

**See verses 7 to 10 from Grahaṇa Vāsanā, in Siddhānta Śiromaṇi.

†See page 127, of the *Translation of S.S.* by Burgess. Whitney suggests that these values were borrowed by Hindus from the Greeks, because the two agree rather closely. But this is simply a biassed view. Any sensible person will admit that in a case like this the difference of even a few minutes must be regarded as considerable.

(7) HELIACAL RISING AND SETTING

(EMERSION AND IMMERSION)

The heliacal rising and setting of planets is a matter of great importance in our country. Religious rites like those of marriage etc. are forbidden when Jupiter and Venus are set. This has mainly raised the importance of this subject and it is believed to be one of the means to test the accuracy of astronomical calculations in the light of observation.

When planets and stars are in the proximity of the sun, they are not visible before sunrise and after sunset, even though they are themselves on the horizon and the sun has not appeared above the horizon. The planets and stars thus continue to remain invisible for a week, a fortnight or for some months. After the stars and planets first become visible, their distance from the sun gradually diminishes till at last a day comes when they become invisible. They are then said to have 'set' on that day. Again, after they first become invisible being near to the sun, their distance from the sun begins to increase gradually, till a day comes when they emerge from its light and become visible. This phenomenon is termed the 'rise'. The diurnal phenomenon of the appearance and disappearance above and below the horizon of the stars and planets is called the '*udayāsta*' (*i.e.* rise and set) ; and their disappearance due to their proximity with the sun and reappearance,—these phenomena also are termed '*astodaya*' (*i.e.* set and rise). It will thus be seen that the words 'rise and set' are used in two senses. It is desirable that the two phenomena should be known by different names. These are distinct terms in the case of the moon. During the dark half of the month as the moon gradually approaches the sun, her distance diminishes, till on the new moon day she disappears and then makes her first appearance in the west on the first or second lunar day after the new moon day. The phenomenon is then called *Candra-daśrana* (first appearance of the moon). They do not characterize it as the rising of the moon. It is similarly desirable to speak of the first appearance of stars and planets after they have disappeared owing to their proximity with the sun, as their 'darsana' (emersion) and their first disappearance as the 'adarśana' (immersion). But most of our astronomers have indiscriminately used the terms 'Udayāsta' (rise and set) even for the phenomena of appearance and disappearance due to their nearness to the sun and the same terms are in use at present. People give much consideration to the daily rising and setting of the moon and it is very necessary for them. Similarly people use to notice its first appearance when it is very near the sun ; hence in her case they naturally found it neeessary to use different terms for the two phenomena. But no one ever cares much to think about the daily rising and setting of planets and stars ; and hence it appears that they began to apply the term "rise and set" to their appearance and disappearance depending upon their proximity to the sun.

Social rites like the thread ceremony and marriages and so also penances, house foundation, etc., are not performed wben Jupiter and Venus are 'set'.

नीचस्थे वक्रसं स्थेप्यतिचरणगते बालवृद्धास्तगे वा
संन्यासो देवयात्राव्रतनियमविधिः कर्णवेधस्तु दीक्षा ।।
मौंजीबंधोंगनानां परिणयविधिर्वास्तुदेवप्रतिष्ठा
वर्ज्याः सद्भिः प्रयत्नात् त्रिदशपतिगुरौ सिंहराशिस्थिते वा ।।

लल्ल.

बाले वा यदि वा वृद्धे शुक्रे वास्तंगतो गुरौ । मलमास इवैतानि वर्ज्ययेद्देवदर्शनम् ॥

बृहस्पति·

"Good people should as far as possible avoid performing social and religious ceremonies like 'Sanyās' (initiation into Sanyāsī life), pilgrimage to a holy place, penance, perforation of ears, thread ceremony, marriages, etc., when Jupiter, the preceptor of gods, is in its fall or retrograde, has very swift motion, is in its 'childhood' or 'old age', or occupies the sign *LEO*.

—Lalla

"Visiting temples (places of gods) for darśana should not be undertaken if Venus or Jupiter are very young or very old, or if they are 'set', for these conditions are as inauspicious as the intercalary month".

—Bṛhaspati

The compilers of works on Dharmaśāstra have made these and similar other statements. Now-a-days ceremonies like marriage are postponed only when Jupiter and Venus are 'set' (heliacally). No one generally cares to know their positions, like fall, retrogression or very swift motion. Anyway, of all the planets and stars the 'setting' of only Jupiter and Venus, is taken as unfavourable for the performance of religious rites. These two planets are far more brilliant than the other planets. As for the nakṣatras some nakṣatra or other is always set. The set of Mercury occurs about six times during a year. The 'set' of Mars occurs after a long period ; but once it is set, it is not visible for five months. Hence the fact that the 'sets' of Mercury, Mars and nakṣatras are not treated as impediments to the performance of religious rites shows the tendency of Dharmaśāstra to remain ***in harmony with practical life***. Again, it should also he borne in mind that the compilers of Dharmaśāstra did not consider whether to accept or reject the 'set' of Saturn for daily affairs, even though it did not come in the way of practical life. Its set may not have been considered worth rejection because it happens to be a malefic planet.

A planet that is due to 'set', rises in the east, actually sets (heliacally) when the difference between the moments of sunrise and that of the planets' daily rise becomes less than a particular amount of time and it rises (heliacally) when such difference exceeds that amount of time. Similarly the planet's rise and set in the west are governed by the difference in the moment of sunset and that of the planet's daily setting. Rules like these had been framed by our ancient astronomers. For example, Jupiter rises or sets (heliacally) when a difference of about 110 palas occurs between the moment of the daily rising and setting of the sun and Jupiter. The diurnal rotation of the earth carries the planets through 1° in 10 palas which gives 11° in 110 palas. Because these degrees (aṃśas) are related to time (kāla) they are termed 'Kālāṃśas' (time expressed in degrees). It has been mentioned that when a difference of 11 'kālāṃśas' occurs between the sun and Jupiter the latter either rises or sets. The followiog table gives the Kālāṃśas relating to planets, as mentioned in different works :—

	ORIGINAL S.S.	Modern Sūrya : Romaśa : Ś.-Brahma : Soma : Sid.	First Ārya Siddhānta	Brahmagupta : Siddhānta Śiromaṇi	Lalla : Karṇa Kutūhala	Second Ārya Sid.	Karṇa Prakāśa	Grahalāghava	Keropant's planetary tables	Ptolemy	Author's experience
Moon . .	12	12	12	12	12	12	12	12	12		12¼
Mars . .	17	17	17	17	17	17	17	17	17	14½	17
Mercury .	13	14	13	14	13	13	13	13	13	11½	13
Mercury (Retro)		12		12	12	12½		12			
Jupiter . .	11	11	11	11	11	12	12	11	11	12¾	11
Venus . .	9	10	9	10	9	8	9	7	9	5⅔	8
Venus . (Retro) .		8		8	8	7½		6			
Saturn . .	15	15	15	15	15	15	15	15	15	14	15

Out of these, the Kālāṃsas of PTOLEMY*, are true for the planets when they are situated in the sign of Cancer and those for Mercury and Venus are related to their western sets.

The kālāṃśas given by Keropant in his Planetary Tables are the same as those given by the Ārya Siddhānta. He does not appear to have given them as determined by his own experience since they are not found completely to agree with observed results.

The compilers of the almanacs, published by Ganpat Krishnaji and the Nirnaya Sagar Press, calculate the rise and set of only Venus on the basis of the Kālāṃśas of the Grahalāghava. The times of the rise and set of all other planets in these almanacs and even those of Venus in other almanacs following the Grahalāghava system, are calculated by a crude method given by the Grahalāghava. Other almanacs in this country may be finding the rises and sets of planets on the basis of Kālāṃśas given in the works which they may be adopting as their authority. The new almanacs compiled with the help of the Nautical Almanac viz. the Keropanti i.e. Patwardhani Pañcāṅga that by Daivaji at Varanasi and our sāyana almanac find the times of the rise and set on the basis of kālāṃśa figures given by some ancient work or other. Not all the timings thus calculated are found to be correct in the case of any almanac. Some of them are correct and some are not. Now it is true that they are not as often wrong in the case of the new almanacs as in that of the old ones.

*See page 223, Translation of the S.S. by Burgess.

Some persons begin to maintain, therefore, that the calculations of even the new almanacs are at times as wrong as those of the Grahalāghava, simply because some of the timings in the new almanacs appear to be incorrect, without caring to consider why they seem to be incorrect. It cannot be argued that the calculations of the new almanacs are erroneous because the times of rises and sets given by them are not sometimes found to be correct. It can be proved from plenty of other evidence that their calculations are correct. The reasons for the failure of such timings are quite different. The main reason for the failure lies in the error in the Kālāṃśa adopted. The planetary places as obtained from the Grahalāghava are at present found to be always erroneous to a certain extent. If the rises and sets calculated from it are sometimes found to be true it is merely by coincidence. In order to determine the Kālāṃśas for a planet, either the difference in the moments of day to day rises and sets of the sun and the planet should be actually observed and recorded or they should be determined by calculation on the basis of the calculated positions of the sun and the planet. The sun, however, is immediately visible when it comes to the horizon. But the chance of observing the rise or set of a planet lasts for a short time before sunrise or after sunset. But as there is twilight at that time no planet is visible when it is on the horizon ; it is visible only when it is somewhat above the horizon. Hence, the difference in the daily rise or set of the planets and the sun cannot be found correctly by actually observing them. Even if it were possible to have some means by which to find them, there was no possibility of people in ancient times possessing fine instruments for measuring time and angles with great precision as at present. Again, in order to find by calculation the difference in times of the day to day rises and sets of the sun and the planets from their positions at heliacal rises and sets, it is necessary that the positions be very accurately known. If it be correct, in other words, if it be accurately known that a particular planet is occupying a certain position or is situated at a particular distance from the sun, the time would be correctly calculated. But we do not think that in those ancient times when the Kālāṃśas were determined, the calculation of planets' places used to be extremely minute-in fact, so minute that there would be no room even for the error of a 'pala' in the timing of daily rise and set.

On account of these reasons, there was every possibility of errors having crept into the kālāṃśas determined in those times. If the kālāṃsas that are the very foundation of determining the (heliacal) rise and set, be erroneous, how could the times of the rise and set calculated on their basis found to be correct ?

In the sāyana almanac we adopt 11 as the kālāṃśa for Jupiter ; hence, we can say for certain that the difference in moments of the daily sets of Jupiter and the sun is definitely less than 110 palas on the day which the almanac has shown as the day of Jupiter's heliacal setting and can be verified and found correct by other means. But it is a difficult question altogether whether Jupiter will definitely set on that day on which the difference in times of the daily sets of Jupiter and the sun becomes less than 110 palas. Perhaps the set might take place a day or two earlier or later, and even it so happens it does not follow that the calculations of the new almanacs are wrong. It can, at the most, mean that the kālāṃśas of Jupiter ought be changed to a quantity more or less than 11°.

In the present times we have the means to test the accuracy of the places of planets and instruments to record the time correctly. The Kālāṃśas should be determined in such times. An attempt was made to do this for six or seven years up to Śaka 1811 ; but later on the author did not get leisure owing to several other pursuits. His eyesight too began to grow weaker gradually, but still he is carrying* on the observation work to some extent personally and with the help of keen-sighted students.

MR. GOPAL BALLAL BHIDE**, a member of the group interested in the sāyana almanac, helped him much by his efforts in this direction. The work of finally determining the rules for the heliacal rise and set of planets, after coordinating the results of all our observations has not yet been completed. The rises and sets of Saturn used to occur mostly in the rainy season or about that time during five years preceding Śaka 1811 and hence we did not get an opportunity for observing them. We got the chance of observing the phenomena about Mars only once or twice. If any of the readers feels inspired by this and communicates to him his experiences in this subject, he would be doing a great service to the Science of Astronomy. The sky is sometimes cloudy even in summer ; the planets when they are on the point of rising or setting, are situated very close to horizon. Many such obstacles come in the way of taking observations. It has, however, been gathered from experience, that the kālāṃśa mentioned in our old works are tolerably accurate. It is true that Mercury and Venus appear brighter when they are retrograde; however, the variation in their *kālāṃśas* mentioned by some works as due to their direct or retrograde motion is far from correct—as a matter of fact one may safely say that the variation is next to nothing.

A NOTEWORTHY PECULIARITY

A peculiarity relating to rise and set has come to the notice, which had not struck any author of our ancient works. When planets are about to set or rise heliacally, they are situated very near the sun. Their visibility depends upon their luminosity ; and the luminosity varies according to their *altitude i.e height above the horizon ;* and even if the time-interval between the planet's diurnal rise and sunrise be the same at different places on the earth, still the altitude of the planet would be different. Its altitude at a place in latitude of 25° North would be less than that at a place in latitude 15° North and accordingly the luminosity wil be less ; and its (heliacal) rise in 25° North latitude will take place some days after it has occured at a place in North latitude 15°, while its set will take plaee earlier. It can be mathematically proved by means of a diagram that even when kālāṃsas be the same, that is to say, even if the time-interval between the daily rise or set of a planet and that of the sun be the same, their altitudes and hence their

*The author had written an essay on the subject of rise and set of planets in the *Srishtijnan*, a monthly Journal formerly published in Bombay, in the issues for May, June and July 1855. A chapter on the same subject, in his book *Jyotirvilas* may also be seen in addition to this.

**Gopal Ballal Bhide used to take a keen interest in observing celestial phenomena. He was born in Śaka 1778 at Nirvedi, in Ratnagiri District and died in Śaka 1812. He was in the service of the Education Department in that district from 1874 A.D. to the end. He had recorded several observations about the rises and sets of planets, and had also seen the rises and sets of the junction stars of some of the naksatras. Had he lived longer, he would have been of great use in promoting the cause of the Sclience of Indian Astronomy.

(heliacal) rises and sets will vary with the latitudes of different places ; but it is not proposed to do so here for want of space. It will be easily understood from what follows. The twilight lasts for a longer time in England than in our country. If Venus, for instance, rose (diurnally) 32 min. earlier than the sun on a particular day (that is, if its kālaṃsas were 8), it would be visible in our country on that day, but will not be visible in England, even though it rose there 32 min. earlier than the sun, which means that its heliacal rise will not occur that day, but a number of days afterwards. If Venus has a north declination, and if it rises 32 min. before the sun in our country, it will have its daily rise in England more than 32 min. earlier. This means that if we consider only the kālāṃsas, Venus should rise heliacally some days earlier in England than in India ; but experience will show a contrary result. Even at the same given place, although the kālāṃśa given for a planet be the same, its altitude will vary according to its declination, north or south. The variation in this case will not, however, be considerable. In short, the kālāṃśas for a planet should increase in value as the terrestrial latitude rises higher north of equator ; and secondly it is better to establish the rules for heliacal rise and set on the basis of altitudes rather than that of kālāṃśa.

These considerations about the factor of altitude and the author's own experience at *Barsi* (lat. 18° 13′) have convinced him that the kālāṃśas mentioned in our old works were determined in our own country. As for kālāṃśas of *Ptolemy* it can be easily seen that they had no connection whatsoever with our works. On the contrary it can be said about Ptolemy's kālāṃsas that they had not been determined through experience, or if determined, the positions of planets on which they were based were erroneous, else he might have committed some other error. The kālāṃsas of Mars, Mercury and Venus do not amount to anything less than 16°, 12°, and 8° at 18° north latitude. These must therefore, be greater at Alexandria (latitude 31° 13′N). Hence, it follows that the kālāṃśas of Mars, Mercury and Venus mentioned by Ptolemy as $14\frac{1}{2}°$, $11\frac{1}{2}°$, and $5\frac{2}{3}°$ are considerably wrong. The kālāṃśas for rise and set, as also the altitudes, true for a particular place can be determined with precision. Even when they are so determined, the experience regarding kālāṃśas will be found to vary because of moon light, the reddish light seen at times near the horizon and the relative strength of the observer's eye-sight*. The clouds too serve as another obstructive factor. Hence, it was proper that our authorities on Dharmaśāstra have recommended the omission of few days after and before the mathematically obtained days of planets' rises and sets, because of 'childhood' and 'old age of the planets.

The kālāṃśas which are based on actual experience and which are used for the sāyana almanac have been given above. It is the experienee of G. B. Bhide at Hedavi (lat. 17° 20′N), that sometimes the kālāṃśa of Mercury at the time of rise or set is 11° that of Jupiter 10° and that of Venus is $7\frac{3}{4}°$

*It has been my experience that if a weak-sighted person may not be able to see the rise of a planet even for three or four days after it has been seen by a keen-sighted person the times of rises and sets are more likely to go wrong when the difference in the motions of the sun and the planet is very small.

(8) 'ŚṚṄGONNATI'
OR
ELEVATION OF THE MOON'S CUSPS

A very small portion of the moon's disc is illuminated in the first week of the bright half and the second week of the dark half of the month. It is termed Śṛṅga (horns) or cusp (of the moon). The subject matter of the chapter on Śṛṅgonnati is to find what end of the moon's cusp would appear elevated and in what direction and what part of the moon's disc will be illuminated on the earlier days of the bright half at the time of sunset and on latter days of the dark half at about sunrise, and particularly on the first or second lunar day of the bright half when the moon's first appearance takes place. The Saṃhitā works discuss at great length the effects due to the elevations of the moon's cusps. The moon becomes illuminated because of the sun, and the moon's cusps will appear elevated on that side on which the sun stands. This has, of course, nothing to do with good or evil events on the earth ; but it is natural for such beliefs to gain ground when the real causes are not known.

(9) CONJUNCTIONS OF PLANETS

When two planets come very close to each other, they are said to have formed or come into CONJUNCTION. At that moment, the distance between them measured east to west, must be zero. Even then there may be some distance between them, north to south, according to their latitudes. When at the moment of conjunction, their rays are found to intermingle, or when their north-south distance is found to be less than 1°, they are said to be having *yuddha* (fighting), and if the distance exceed 1°, they are said to have formed a *Samāgam* (companionship). If the discs of planets would simply touch, they would be said to have "grazed" *i.e.* formed an '*ullekha*' and when the discs penetrate each other, they are said to have formed a *bheda*' (*i.e.* penetration or occultation). The results of 'bheda' and other types of conjunctions are described at length in Saṃhitā works. The definition and calculation of the 'bheda' type of conjunction are given in our works. It is, however, not known if our people knew the penetration of the sun's disc by Venus (Pages 163-164).

(10) BHA-GRAHA-YUTI
OR
CONJUNCTION OF PLANETS WITH STARS

LONGITUDES AND LATITUDES OF STARS

This chapter describes the calculation of the conjunction of planets with the junction-stars of nakṣatras and for this purpose lists of polar longitudes and latitudes of junction-stars and of some other stars are given. The figures denoting longitudes are generally corrected by "ayana-dṛk-karma-sanskṛta" *i.e.* they are governed by the following conventional definition. 'BHOGA' (*longitude*) is the ecliptic arc between the initial point and the point where the perpendicular drawn from the star to the celestial equator cuts the ecliptic and the ŚARA (*latitude*) is the distance of that point from the star. Let us call such longitudes and latitudes, polar longitudes and polar latitudes. The longitudes and

latitudes in certain works conform to this definition. BHOGA (longitude) is the ecliptic arc between the initial point and the point where the perpendicular drawn from the star to the ecliptic cuts the ecliptic : and the perpendicular so drawn is the Śara (latitude). The pole of the ecliptic is also known as Kadamba. Let these longitudes and latitudes be, therefore, called 'KADAMBĀ-BHIMUKHA' (facing the pole, *kadamba*). On pages 338 and 339, later on, have been given the polar latitudes and longitudes of stars, as given in six works. The polar longitudes and latitudes of those* stars which in the author's opinion, should be regarded as junction-stars are also given. The correction due to 'ayana-dṛk-karma' is not always the same owing to the shifting of the eqinoxes. Hence the polar longitude of a star will not always remain the same. It may be partly due to this reason that the longitudes of stars mentioned in six works, which have been given below differ from one another to a certain extent ; some differences may be due to the fact that different stars might have been adopted as junction-stars. The *dhruvas* (polar longitudes and latitudes) mentioned by the Sūrya-Siddhānta, Brahmagupta Siddhānta and Lalla Tantra, belong to a period when the amount of ayanāṃsa was exceedingly small. About this BHĀSKARĀCĀRYA remarks :

इत्यभावेऽयनांशानां कृतदृक्कर्मकाध्रुवाः ।

कथिताश्च स्फुटा बाणाः सुखार्थं पूर्वसूरिभिः ॥ १७ ॥

सिद्धांतशिरोमणि, भग्रहयुति.

"Thus have been mentioned (in the absence of any ayanāṃśas) polar longitudes, after the application of the 'dṛk-karma', and also the apparent latitudes, by ancient Riṣis, for the sake of convenience".—Sid. Śiromaṇi, chapter on conj. of planets with stars.

The works of BRAHMAGUPTA and LALLA do not refer to the motion of the ayana-point and the S. S. does refer to it ; still the longitudes of the stars given in the latter agree for the most part with those mentioned by Brahmagupta and Lalla. This shows that Bhāskarācārya's remark applies to the longitudes given by all the three works. Some figures showing longitudes and latitudes in the Sundara Siddhānta are missing, because the procured copy was very inaccurate and those figures were unintelligible.

The polar latitudes and polar (sāyana) longitudes for 1887 A.D. of the junction-stars as adopted by the author, have been calculated from their right ascensions and declinations given in the French Connaissance-des-Tempes. The longitude of Spica thus obtained is 201° 26′ 16″.3. Assuming the longitude of Spica to be 180°, the author has mentioned in the column headed "his opinion" the longitudes of all stars after subtracting from their (Sāyana) longitudes the ayanāṃśa figure 21°-26′-16″.3. These are true for Śaka 1809. The latitudes also are true for the same year. But because the longitudes are nirayaṇa, only a very slight variation will occur in them with the lapse of time. If *Mu Piscivm* be assumed to be the star at the initial point, the longitudes of stars according to "his opinion" will have to be reduced by 1° 20′.

*These very stars have been adopted as *junction-stars* for giving moments of conjunctions in the sāyana almanac since Śaka 1815. The European names of such junction-stars as have been selected by different researchers may be seen in tables given later on.

POLAR LONGITUDES OF JUNCTION STARS AND SOME OTHERSTARS

Serial No.	Names of Stars	Modern S.S. °	′	Brahma Gupta S. °	′	Lalla Tantra °	′	[illegible]rīya B. Tulya °	′	Sundara S. °	Graha-lāghava °	Author's opinion °	′
1	Āśvinī	8		8		8		8	30	8	8	7	43
2	Bharaṇī	20		20		20		21	15	20	21	21	51
3	Kṛttikā	37	30	37	28	36		37	45	38	38	36	2
4	Rohiṇī	49	30	49	28	49		49		50	49	47	37
5	Mṛgaśiras	63		63		62		62		63	62	61	26
6	Ārdrā	67	20	67		70		66		67	66	75	43
7	Punarvasu	93		93		92		92	45	93	94	91	21
8	Puṣya	106		106		105		106		106	106	105	43
9	Āśleṣā	109		108		114		107	15	108	106	108	28
10	Maghā	129		129		128		129		129	129	126	59
11	P. Phālgunī	144		147		139	20	148			148	144	31
12	U. Phālgunī	155		155		154		155	30	155	155	154	1
13	Hasta	170		170		173		170			170	165	6
14	Citrā	180		183		184	20	183		183	183	180	
15	Svāti	199		199		197		198	30	199	198	193	28
16	Viśākhā	213		212	5	212		212	15	212	212	202	11
17	Anurādhā	224		224	5	222		224	15		224	219	8
18	Jyeṣṭhā	229		229	5	228		229	30	229	230	225	59
19	Mūla	241		241		241		242			242	240	45
20	Pūrva Āṣāḍhā	254		254		254		255	30	254	255	253	23
21	Uttara Āṣāḍha	260		260		267	20	260		260	261	263	5
	Abhijit	266	40	265		267		259	45		258	256	10
22	Śravaṇa	280		278		283	10	275	15	278	275	272	58
23	Dhaniṣṭhā	290		290		296	20	287	30	290	286	284	47
24	Śatatārakā	320		320		313	20	320		320	320	318	43
25	P. Bhādrapadā	326		326		327		325		326	325	322	3
26	U. Bhādrapadā	337		337		335	20	337		337	337	340	35
27	Revatī	359	50	0		359	0	0		0	0	356 1	57 20
	Agastya	90		87		87				87	80		
	Vyādha	80		86		86				86	81		
	Agani	52								52	53		
	Brahmā	52								52	55		
	Prajāpati	57								57	61		
	Apāmvatsa	180									183		
	Āpas	180											

POLAR LATITUDES OF JUNCTION STARS AND SOME OTHER STARS

Serial No.	Names of Stars	Modern S.S.		Brahma Gupta S.		Lalla Tantra		Dāmodarīya B. Tulya		Sundara S.	Graha-lāghava.	Author's opinion		Direction of latitude
		s	′	s	′	s	′	s	′	s	s	s	′	
1	Aśvinī	10		10		10		10		10	10	9	5	N
2	Bharaṇī	12		12		12		12	15	12	12	10	57	N
3	Kṛttikā	5		4	31	5		4	30	5	5	4	9	N
4	Rohiṇī	5		4	33	5		4	30	4½	5	5	32	S
5	Mṛga	10		10		10		10		10	10	13	24	S
6	Ārdrā	9		11		11		11		11	11	6	46	S
7	Punarvasu	6		6		6		6		6	6	6	46	N
8	Puṣya	0		0		0		0		0	0	0	5	N
9	Āśleṣā	7		7		7		7		7	7	11	24	S
10	Maghā	0		0		0		0		0	0	0	29	N
11	P. Phālgunī	12		12		12		11	45		12	10	31	N
12	U. Phālgunī	13		13		13		12	45		13	13	24	N
13	Hasta	11		11		8		11		11	11	13	17	S
14	Citrā	2		1	45	2		1	45	1¾	2	2	12	S
15	Svatī	37		37		37		37	15		37	32	56	N
16	Viśākhā	1	30	1	23	1	30	1	15		1	0	22	S
17	Anurādhā	3	0	1	44	3		1	45		2	2	1	S
18	Jyeṣṭhā	4		3	30	4		3	30		3	4	37	S
19	Mūla	9		8	30	8	30	8	30		8	13	48	S
20	Pūrva Āṣāḍhā	5	30	5	20	5	20	5	30		5	2	7	S
21	Uttara Āṣāḍhā	5		5		5		5			5S	1	20N	
	Abhijit	60		62		63		62		62	62	61	55	N
22	Śravaṇa	30		30		30		29	30	30	30	29	49	N
23	Dhaniṣṭhā	36		36		36		25	30	36	36	34	15	N
24	Śatatārakā	0	30	0	18	0	20	0	15	2⅛	0	0	25	S
25	P. Bhādrapadā	24		24		24		23	45		24	21	6	N
26	U. Bhādrapadā	26		26		26		26			27	13	45	N
27	Revatī	0		0		0		0			0	0 3	14 18	S
	Agastya	80		77		80				77	76			S
	Vyādha	40		40		40				40	40			S
	Agni	8								8	8			N
	Brahmā	30								30	30			N
	Prajapati	38								38	39			N
	Apamvatsa	3									3			N
	Āpas	9												N

CELESTIAL LONGITUDES OF JUNCTION STARS

Serial No.	Stars	Sūrya Siddhānta		Brahmagupta Siddhānta		2nd Ārya Siddhānta		Sārvabhauma Siddhānta		Venkatesh B. Ketkar		Author's opinion	
		°	′	°	′	°	′	°	′	°	′	°	′
1	Aśvinī	11	59	12	5	12	0	12	40	14	6	10	8
2	Bharaṇī	24	35	24	41	24	23	25	8	28	20	24	22
3	Kṛttikā	39	8	38	58	38	33	39	2	40	7	36	9
4	Rohiṇī	48	9	48	11	47	33	48	9	49	55	45	57
5	Mṛgaśiras	61	3	61	0	61	3	61	1	63	50	59	51
6	Ārdrā	65	50	65	5	68	23	65	8	68	53	75	16
7	Punarvasu	92	52	92	52	92	53	92	53	93	22	89	24
8	Puṣya	106	0	105	0	106	0	106	0	108	51	104	53
9	Aśleṣā	109	59	108	58	111	0	108	56	113	46	110	44
10	Maghā	129	0	129	0	129	0	129	0	129	58	126	0
11	P. Phālgunī	139	58	142	45	140	23	142	48	143	32	139	34
12	U. Phālgunī	150	10	150	4	150	23	149	40	151	45	147	47
13	Hasta	174	22	174	28	174	3	175	13	173	35	169	37
14	Citrā	180	48	183	49	182	53	183	50	183	58	180	0
15	Svātī	183	2	182	41	184	0	182	24	184	22	180	24
16	Viśākhā	213	31	212	34	212	53	212	36	211	8	201	14
17	Anurādhā	224	44	223	33	224	53	224	38	222	42	218	44
18	Jyeṣṭhā	230	7	230	4	230	3	230	5	229	54	225	56
19	Mūla	242	52	242	48	242	44	242	16	243	0	240	44
20	Pūrva Āṣāḍhā	254	39	254	0	254	33	254	34	254	42	252	28
21	Uttara Āṣāḍhā	260	23	259	37	260	23	260	21	262	47	262	24
	Abhijit	264	10	260	46	263	0	262	10	265	26	261	28
22	Śravaṇa	282	29	280	3	280	3	280	3	281	53	277	55
23	Dhaniṣṭhā	296	5	296	15	295	33	294	12	297	31	293	33
24	Śatabhiṣak	319	50	319	54	319	53	319	54	321	42	317	44
25	P. Bhādrapadā	334	25	334	46	334	53	336	8	334	40	330	42
26	U. Bhādrapadā	347	16	347	29	347	0	348	44	354	26	345	19
27	Revatī	359	50	0	0	0	0	359	50	0	0	356 359	2 17

CELESTIAL LATITUDES OF JUNCTION STARS

Serial No.	Stars	Direction of Latitudes	Sūrya Siddhānta		Brahmagupta Siddhānta		2nd Ârya Siddhānta		Sārvabhauma Siddhānta		Venkatesh B. Ketkar		Author's opinion	
			°	′	°	′	°	′	°	′	°	′	°	′
1	Aśvinī	N	9	11	9	8	10	0	10	55	8	29	8	29
2	Bharaṇī	N	11	6	11	11	12	0	12	56	10	26	10	26
3	Kṛttikā	N	4	44	4	15	5	0	4	44	4	2	4	2
4	Rohiṇī	S	4	49	4	28	5	0	4	40	5	28	5	28
5	Mṛgaśiras	S	9	49	9	48	10	0	10	13	13	23	13	23
6	Ārdrā	S	8	53	10	50	11	0	11	7	16	3	6	45
7	Punarvasu	N	6	0	6	0	6	0	6	0	6	40	6	40
8	Puṣya	N	0	0	0	0	0	0	0	0	0	4	0	4
9	Āśleṣā	S	6	56	6	56	7	0	7	4	5	5	10	59
10	Maghā	N	0	0	0	0	0	0	0	0	0	28	0	28
11	P. Phālgunī	N	11	19	11	14	12	0	12	42	9	42	9	42
12	U. Phālgunī	N	12	5	12	2	13	0	13	55	12	16	12	16
13	Hasta	S	10	6	10	4	10	0	12	4	12	11	12	11
14	Citrā	S	1	50	1	50	2	0	1	52	2	3	2	3
15	Svatī	N	33	50	33	41	37	0	41	5	30	49	30	49
16	Viśākhā	S	1	25	1	18	1	30	1	25	1	48		
17	Anurādhā	S	2	52	1	39	3	0	1	50	1	58	1	58
18	Jyeṣṭhā	S	3	50	3	22	4	0	3	37	4	33	4	33
19	Mūla	S	8	48	8	19	9	0	8	40	6	36		
20	Pūrva Âsāḍhā	S	5	28	5	18	5	20	5	22	6	27	2	7
21	Uttara Âsaḍhā	S	4	59	4	59	5	0	5	1	3	27	N1	27
	Abhijit	N	59	58	61	56	63	0	62	14	61	44	61	44
22	Śravaṇa	N	29	54	29	56	30	0	30	5	29	18	29	18
23	Dhanisṭhā	N	35	33	35	32	36	0	26	25	33	2	33	2
24	Śatabhisak	S	0	28	0	17	0	20	0	20	0	23	0	23
25	P. Bhādrapadā	N	22	30	22	26	24	0	26	3	19	23	19	23
26	U, Bhādrapadā	N	24	1	23	56	26	0	28	28	25	41	12	36
27	Revatī	S	0	0	0	0	0	0	0	0	0	13	0 3	13 4

The celestial latitudes and longitudes calculated from the polar latitudes and longitudes given by the Ṣūrya-Siddhānta and the Brahmagupta Siddhānta* have been given in tables on pages340-341. The latitudes and longitudes given by the second ĀryaSiddhānta appear to be celestial (based on the pole of the ecliptic) and hence are given in the same table. It has been clearly mentioned in the Sārvabhauma Siddhānta that the longitudes and latitudes given in it are celestial and hence they are also given in the table. The celestial latitudes and longitudes calculated by the author and Ketkar were first calculated from the *French or English Nautical Almanac.* Longitudes given by Ketkar are nirayaṇa and are measured from the star, *Zeta Piscium,* which he assumed as the initial point, and his ones have been calculated by assuming the longitude of Citrā to be 180°. Otherwise, our figures are, in fact, identical. Seven of his junction stars are, however, different from those of Ketkar. Their longitudes and latitudes are, therefore, actually different. The author has given two figures for the star Revatī. The first belongs to Zeta Piscium and the second to Mu Piscium. If Mu Piscium be taken as the initial point, 43 minutes will have to be added to the longitude of each star.

The PAÑCASIDDHĀNTIKĀ has not recorded the polar longitudes of stars as given in the original Sūrya-Siddhānta. It appears that they had been given in the original. ĀRYABHAṬA I has mentioned nothing about the junction stars of nakṣatras. BHĀSKARĀCĀRYA has adopted the polar longitudes and latitudes of nakṣatras from BRAHMAGUPTA.

AL BERUNI has quoted latitudes and longitudes as given by Brahmagupta, some of which are different from those given by the author. They are :— longitude of Uttarā Bhādrapadā, 336° ; latitude of Mṛga, 5° ; of Āśleṣā 6° ; and of Mūla9½°. Some error in this respect appears to have crept into Beruni's work either in the original or in its later transcriptions. The figures denoting Brahmagupta's longitudes and latitudes are given in code words in verse form in the original, and they are the same, both in the Brahmagupta Siddhānta and in Khaṇḍakhādya ; and the author has collected them from four different copies of the work, so that there is no doubt about their reliability. Brahmagupta has in the beginning given the latitudes of Kṛttikā, Rohiṇī, Citrā, Viśākhā, Anurādhā and Jyeṣṭhā respectively as 5, 5, 2, 1½, 3, and 4 and Beruni has quoted them thus. But Brahmagupta has immediately added that these latitudes must be reduced by certain number of minutes each. Accordingly his figures have been given after reduction, but Beruni has not done so. The latitude of Mūla has been given in the original as "ardhanavama". Beruni has assumed this to be 9½°. But the word "ardhanavama" means 8½°.

As for the polar longitudes, according to the modern Sūrya-Siddhānta given above, there is a difference of opinion about Ārdrā. It appears from the remarks of *Ranganath,* the commentator of the Sūrya-Siddhānta that according to *Narmad,* the longitude of Ārdrā is 73° 47′, and according to *Parvat,* 73° 10′ ; and he also adds that according to popular view, it is 74° 50′. But the longitude of Ārdrā as given by the Śākalya Saṃhitā is 67° 20′ only and Ranganath has accepted it**. Kamalakara, the author of the Siddhānta-

*The longitudes and latitudes of the S.S. have been given as calculated by Whitney by the methods given in that Siddhānta, and those for Brahma Siddhānta have been taken from Bentley's book and they are calculated by Bently himself.

**The polar longitudes of stars as given by the modern Sūrya-Siddhānta, the Romaśa, Śākalya's Brahma Siddhānta, and the same are given in units of ten minutes each, measured from the initial point of the corresponding nakṣatra division. The Sūrya-Siddhānta has cited the longitude of Ārdrā as "abdhayah" *i.e.* 4. One comes across other reading also like "gobdhayah" meaning 49, and 'gognayah' meaning 39.

tatva-viveka, has accepted all the longitudes and latitudes as in the Sūrya-Siddhānta, but has taken 74° 50′ as the longitude of Ārdrā. The modern Romaśa, Soma and Śākalya's Brahma Siddhāntas are followers of the Sūrya-Siddhānta and these contain the same longitudes and latitudes of stars as in the Sūyra-Siddhānta. There is, however, a difference of view about Ārdrā. Śākalya's *Brahmasiddhānta* has given longitudes and latitudes as mentioned above. The Soma Siddhānta gives 74° 50′ as the longitude of Ārdrā. The figures for all the remaining longitudes and latitudes are identical with those of the Sūrya-Siddhānta. The author had procured two editions of the Romaśā Siddhānta. Some of the longitudes given in them are different from those of the Sūrya-Siddhānta but the difference seems to be due to copyist's errors. One may safely say, therefore, that the polar longitudes and latitudes given by the *Romaśa Siddhānta* are almost the same as those of the *Sūrya Siddhānta.*

In the Sūrya Siddhānta, the longitudes and latitudes of Agastya (Canopus) Vyādha (Sirius), Agni and Brahmā have been given in three verses (Adhikāra 8). But they are not immediately followed by the verses relating to Prajāpati ; Apāṃvatsa and Āpa have not been immediately given. The longitudes and latitudes of Prajāpati and the other two stars have been repeated in verses 20 and 21 in the end. It, therefore, appears that these verses may have been interpolated later on. In the 9th *Adhikāra* (Chapter) certain stars which never set are mentioned and they include Brahmahṛdaya as one. Hence, Prajāpati-one of above three stars—ought to have been included in the list, because the latitude of Prajāpati is 8° more to the north than that of Brahmahṛdaya. In spite of this it has not been included, which shows that these verses may have been interpolated later. However, one of these stars, Apāṃvatsa, is referred to in the Bṛhat-Saṃhitā*. This shows that all these three stars were known in Śaka 427 also. Prof. Whitney** observes that the star Prajāpati, Apāṃvatsa and Āpa have not been mentioned in Śākalya's Brahmasiddhānta, but that is wrong. They occur in all the three siddhāntas, Śākalya Brahma, Romaśa and Soma. Of these, only Āpa has not been mentioned by the Grahalāghava. Śākalya's Brahmasiddhānta has given the longitudes and latitudes of Saptarṣis (the Great Bear), which are not found in any other work. The YANTRA RĀJA has given sāyana longitudes and latitudes of 32 stars. The SIDDHĀNTA RĀJA has given those for 84 stars.

NUMBER OF STARS IN ASTERISMS

Some nakṣatras consist of only one star and some have many. In the case of those which have many stars, their junction star is indicated by its position and description by Sūrya and three other Siddhāntas, and these descriptions are almost similar ; but they do not help in identifying the junction star correctly. Of the four Siddhāntas, the Śākalya Brahmasiddhānta alone has mentioned the number of stars in each nakṣatra, while others have not. A mere indication of the direction without the number of stars is not of much avail. Apart from Śākalya Brahmasiddhānta, it is only the Khaṇḍakhādya among other astronomical works which has mentioned the junction stars, as also the number of stars in the nakṣatra. They are found in some Saṃhitā

*"Samamuttareṇa tārā chitrāyāḥ kirtyate apāmvatsaḥ"—meaning "The star Apamvatsa is described as situated exactly to the north of Chitrā"—Bṛihat-Saṃhitā, Chapter 25, Verse 4.

**See page 218, Translation of the S.S. by Burgess.

Serial No.	Names of Stars	Taittirīya Śruti	Nakṣatra Kalpa	Vṛddha Garga Saṃhitā	Nārada Saṃhitā	Varāha Mihira	Khaṇḍa Khādya	Lalla's Ratna-kośa	Śākalya Brahma Sidd.	Śrīpati's Ratna-mālā	Muhūrta Tatva	Muhūrta Cintāt maṇī
1	Aśvanī	2	2	2	3	3	2	3	2	3	3	3
2	Bharaṇī		3	3	3	3	3	3	3	3	3	3
3	Kṛttikā	7	6	6	6	6	6	6	6	6	6	6
4	Rohiṇī	1		5	5	5	5	5	5	5	5	5
5	Mīga		3	3	3	3	3	3	3	3	3	3
6	Ārdrā	1 or 2	1	1	1	1	1	1	1	1	1	1
7	Punarvasu	2	2	2	4	5	2	4	2	4	4	4
8	Puṣya	1	1	1	3	3	1	3	3	3	3	3
9	Āśleṣā		6	6	5	6	6	5	5	5	5	5
10	Maghā		6	6	5	5	6	5	5	5	5	5
11	P. Phālgunī	2	2	2	2	8	2	2	2	2	2	2
12	U. Phālgunī	2	2	2	2	2	2	2	2	2	2	2
13	Hasta		5	5	5	5	5	5	5	5	5	5
14	Citrā	1	1	1	1	1	1	1	1	1	1	1
15	Svātī	1	1	1	1	1	1	1	1	1	1	1
16	Viśākhā	2	2	2	2	5	2	4	2	4	4	4
17	Anurādhā		4	4	4	4	4	3	3	4	4	4
18	Jyeṣṭhā	1	..	3	3	3	3	3	3	3	3	3
19	Mūla	1 or 2	..	6	11	11	2	11	9	11	11	11
20	Pūrva Āṣāḍhā		4	4	4	2	4	2	4	4	4	2
21	Uttara Āṣāḍhā		4	4	2	8	4	2	4	4	3	2
	Abhijit	1		3	..	..	3	3	3	3	3	3
22	Śravaṇa	1	3	3	..	3	3	3	3	3	3	3
23	Dhaniṣṭhā	4	5	4	..	5	5	4	5	4	4	4
24	Śatabhiṣak	1	1	1	100	100	1	100	100	100	100	100
25	P. Bhādrapadā		2	2	2	2	2	2	2	2	2	2
26	U. Bhādrapadā	4	2	2	2	8	2	2	2	2	2	2
27	Revatī	1	1	4	32	32	1	32	32	32	32	32

JUNCTION STARS

European astronomers have prepared catalogues of most of the stars visible to the naked eye during the last two or three centuries. They have named those stars and have determined with precision their right ascensions and declinations. The views of different research workers regarding the junction stars of our nakṣatras out of those stars have been given in the table below :—

JUNCTION STARS OF NAKSATRAS

Srl. No.	Names of Stars	Colebrooke	Bentley, Keropant	Whitney, Burgess	Bāpudeva	V. B. Ketkar	The Author
1	Aśvinī	Alpha Arietis	Beta Arietis	Beta Arietis	Alpha Arietis	Beta Arietis	Beta Arietis.
2	Bharaṇī	Mu or 35 Arietis.	35 Arietis	35 Arietis	35 Arietis	41 Arietis	41 Arietis.
3	Kṛttikā	Eta Tauri	Eta Tauri	Eta Tauri	Eta Tauri	Eta Tauri	Eta Tauri.
4	Rohiṇī	Aldebaran	Aldebaran	Aldebaran	Aldebaran	Aldebaran	Aldebaran.
5	Mṛga	Lambda Orionis.	116 Tauri	Lambda Orionis.	Lambda Orionis.	Lambda Orionis.	Lambda Orionis
6	Ārdrā	Alpha Orionis	133 Tauri	Alpha Orionis	Alpha Orionis	Alpha Orionis	Gamma Geminorum.
7	Punarvasu	Pullux	Pollux	Pollus	Pollux	Pollux	Pollux.
8	Puṣya	Delta Cancri	Delta Cancri	Delta Cancri	Delta Cancri	Delta Cancri	Delta Cancri.
9	Āśleṣā	Alpha Cancri	49 Cancri	Epsilon Hydrae	Alpha Cancri	Alpha Cancri	Zeta Hydrae.
10	Maghā	Regulus	Regulus	Regulus	Regulus	Regulus	Regulus,
11	Pūrva Phālgunī	Delta Leonis	Theta Leonis	Delta Leonis	Delta Leonis	Theta Leonis	Theta Leonis.
12	Uttara Phālgunī	Denebola	Denebola	Denebola	Denebola	Denebola	Denebola.
13	Hasta	Gamma or Delta Corvi.	Delta Corvi	Delta Covri	Gamma or Delta Corvi.	Delta Corvi	Delta Corvi.
14	Citrā	Spica	Spica	Spica	Spica	Spica	Spica.
15	Svatī	Arcturus	Arcturus	Arcturus	Arcturus	Arcturus	Arcturus.
16	Viśākhā	Alpha or Kapp Librae.	24 Librae	24 Librae	Alpha or Kappa Librae.	24 Librae	Alpha Librae.
17	Anurādhā	Delta Scorpii	Beta Scorpii	Delta Scorpii	Delta Scorpii	Delta Scorpii	Delta Scorpii.
18	Jyeṣṭhā	Antares	Antares	Antares	Antares	Antares	Antares.
19	Mūla	Nu or 34 Scorpii.	34 Scorpii	Lambda Scorpii	34 Scorpii	45 Ophiuchi	Lambda Scorpii.
20	Pūrva Āṣādhā	Delta Sagittarii	Delta Sagi	Delta Sagi	Delta Sagi	Delta Sagi	Lambda Sagittarii
21	Uttara Āṣādhā	Tau sagittarii	Phi Sagi	Sigma Sagi	Tau Sagi	Sigma Sagi	Pi Sagi.
	Abhijit	Wega	Wega	Wega	Wega	Wega	Wega.
22	Śravaṇa	Altair	Altair	Altair	Altair	Altair	Altair.
23	Dhaniṣṭhā	Alpha Delphini	Alpha Delph	Beta Delphi	Alpha Delph	Alpha Delph	Alpha Delphi.
24	Śatabhisak	Lambda Aquarii.	Lambda Aquarii.	Lambda Aquarii.	Lambda Aquarii.	Lambda Aquarii	Lambda Aquarii.
25	P. Bhādrapadā	Markab	Markab	Markab	Markab	Markab	Markab.
26	U. Bhādrapadā	Alpheratz	Algenib/Alpheratz.	Algenib/Alpheratz.	Alpheratz	Alpheratz	Algenib.
27	Revatī	Zeta Piscium	Zeta Piscium	Zeta Piscium	Zeta Piscium	Zeta Piscium	Zeta or Mu Piscium.

works. Opinions differ regarding the number of stars in a nakṣatra. On page 344 the number of stars in nakṣatras have been given in a tabular form according to 11 different works. First come those stars which can be definitely known on the basis of information gathered from the Taittirīya Śruti given in part I. Nakṣatra Kalpa* is an appendix to the Atharvaveda. Mahādeva, the commentator of Śrīpati's Ratnamāla has given the number of stars as mentioned by Lalla and those have been reproduced here. These may probably have been borrowed from the Ratnakoṣa.

From all considerations, it appears that although there may be a difference of opinion regarding the number of stars in each nakṣatra (*asterism*) there is no difference of opinion as regards the identification of any '*cluster of stars.*' The word śata' (hundred) in the name śatabhiṣak' has led to the misunderstanding that it contains 100 stars and hence the name Śatabhiṣak was changed into Śatatārā. But this belief seems to have been current since the time of VARĀHA MIHIRA. Similarly, in the opinion of all, the latitude of the junction star of Revatī is zero ; and the longitude also is very nearly zero. Hence, there is no difference of opinion about the junction star of Revatī. There are several stars situated near it in the cluster forming the shape of a Mṛdaṅga (tabor). But it is not that they are exactly 32. It is not known on what basis the number was fixed ; but this number too has been handed down from VARĀHA'S TIME. If the regions occupied by all the remaining nakṣatras in the sky be seen, it will be found that every assumption regarding the number of stars has some basis or other. Hence the numbers of all authors are justifiable.

Among the European scholars Colebrooke has made a comparative study of our nakṣatra system and that of the Arabs, and has considered in full details the question of the names and places of our junction stars in the light of the European system. Sir William Jones had done it (in 1790 A.D.) before him, but it was inadequate. Colebrooke's thesis on this subject was published in Vol IX of Asiatic Researches, in 1807 A.D. from which the stars acceptable to Colebrooke, have been given in the above table. The efforts made by Colebrooke have been of much use for later investigators. A book entitled *A Historical View of Indian Astronomy* by BENTLEY was published at Calcutta in 1823. He has considered in it the stars on the basis of their longitudes and latitudes given by BRAHMAGUPTA. The junction stars of his choice have been given from the book in the above table. Among these, he has given only Algeib as the star for Uttarā Bhādrapadā. KEROPANT, however, has taken Alpheratz in its place. Excepting this, KEROPANT has taken all the stars as in the list of BENTLEY**. In addition to the above, Bentley has suggested some other stars as alternative. They are :—Gamma Arietis for Aśvinī ; 113, and 117 Tauri for Mṛga ; 50 Cancri for Āśleṣā ; 71 Leonis for Pūrvā Phalgunī ; 8 Corvi for Hasta ; 35 Scorpii for Mūla. WHITNEY has made a very detailed study*** of this subject ; and has determined the junction stars after careful consideration. BAPUDEVA'S Junction stars have been given

*The author has not yet actually seen the works Nakṣatra Kalpa and Vṛddha Garga Saṃhitā himself. He has quoted the number of stars from the information given by Prof. Thibaut in Indian Antiquary, Vol. XIV PP. 43-45. Prof. Thibaut has quoted the lines from Vṛdha Garga Saṃhitā and Khandakhādya. The author has corrected an error committed by him regarding Revatī and Aśvinī.

**See pages 324-25, Planetary Tables.

***See pages 175-220, Translation of S.S.

in the above table from the list given in his English translation of the S.S.* All of them** are according to the choice of COLEBROOKE. But Bapudeva has changed seven of them in his almanac. Thus, he has abondoned his first choice in the case of the junction stars of Aśvinī, Aśleṣā, Viśākhā, Mūla, Uttarāṣāḍhā, Dhaniṣṭhā, Uttarā Bhādrapadā, and substituted Beta- Arietis, Epsilon Hydrae, 24 (Iotā) Libra, Lambda Scorpii, Sigma Sagittarii, Gamma Pegasi; and it is easily seen that these changes are made in conformity with WHITNEY'S views. The author has given the junction stars acceptable to Venkatesh Bapuji Ketkar, from the list which he supplied. He has attempted to establish as much agreement as possible between the longitudes and latitudes of the stars given in our ancient works and those of the stars determined by Colebrooke and others. He has, however, attempted to see that in addition to the above point that the distances between consecutive junction stars be as near to 13°20′ as possible, so that they would be found to occupy a place in their own divisions. It is not proper to adopt a star from the constellation of Mṛga as junction star of Ārdrā. The line "ārdrayā rudraḥ pathamāna eti" (Tai Br.3.1.1) suggests that God Rudra accompanies the constellation of Ārdrā. The star adopted by the author for Ārdrā transits the meridian only 9 minutes earlier than Sirius. There is no other bright star nearer to Sirius in that region.

The above table will show that there is unanimity of opinion about the following 14 stars :—Kṛttikā, Rohiṇī, Punarvasu, Puṣya, Maghā, U. Phalgunī. Citrā, Svātī, Jyeṣṭhā, Abhijit, Śravana, Śatabhiṣak, P. Bhadrapadā and Revatī, Opinion differs regarding the rest. There is no sense in trying to see whose opinion seems probable, because, it cannot be at all claimed that the longitudes and latitudes of stars given in our old works agree completely with those of all or some stars chosen by any one of them. The longitudes and latitudes of stars given by our works may not be found to agree either because they have not been recorded accurately or because, it is not known to what time they belong; or else, because, they have been calculated by the modern method of calculating ancient longitudes and latitudes, which itself may not be quite accurate. Nevertheless the fact remains that they do not agree. Hence, those stars are to be determined as junction stars whose co-ordinates agree at least approximately. It so often happens that one out of the two or three stars in a nakṣatra shows a close agreement in point of latitude but not longitude, while quite another agrees in point of longitude. This being so, some have laid a stress on the agreement in latitude and others in longitude. Some others have paid attention to the direction of their position in the group. Thus each author has paid attention to the direction of their position in the group. Thus each author has some point or other to support his view. When once it is decided that a particular nakṣatra is the same as some particular cluster of the present times, i.e. Bharaṇī is the same as Musca known to Europeans, the question of deciding which star in the cluster is the junction star naturally remains controversial. If, however, some one adopted some star outside the cluster as junction star, it will be a mistake unless he has some ground for doing so. Thus, for instance, there is a cluster of star visible in the sky, known as Mṛga and its Śirṣa" (i.e. the head of the antelope ; Orion). One of the three stars forming the head of the antelope must be taken as the junction

*In the Bibliotheca Indica New Series, of 1860, A.D. he has taken Musca for Bharaṇī ; but in the almanac, he takes 35 Arietis, and hence the author has given the latter in the table.

**It appears that Pi Tauri has been wrongly taken in place of Eta Tauri through an errorr in printing.

star of Mṛgaṣirṣa. But KEROPANT's star is outside the region. This is of course an error. All works have described the shape of the nakṣatra Mūla as resembling the tail of a lion. But Ketkar's star remains far away from the cluster and hence should be taken to be erroneous. The planetary tables by Keropant have given by mistake 27° in place of 37° as the declination of Mūla; Ketkar appears to have committed the error because of this. Apart from these considerations every investigator can be said to be justified in his views.

CATALOGUES OF STARS

HIPPARCHUS (150 B.C.) was the first in Europe to prepare a catalogue of stars showing their longitudes and latitudes after taking necessary observations. It is not at present available; but PTOLEMY after making allowance for ayana motion, prepared another catalogue (138 B.C.). It is at present available in his work entitled Syntaxis. It contains 1022 stars, grouped into 48 *constellations*. A second Catalogue after this, was prepared by ULUGH BEY, grandson of Tāmerlane, and Emperor of Samarkand in 1437 A.D. It contains 1019 stars. Another catalogue containing 777 stars was prepared by TYCHO BRAHE, in 1600 A.D. Afterwards, several catalogues were prepared in Europe. No one in our country appears to have prepared such a catalogue by taking actual observations. MAHENDRASŪRI has, in his work *Yantrarāja*, given polar longitudes and latitudes of **32** *stars* from the works of Greeks. Malayendu Sūri, the commentator of that work observes,"

शकमतेन नक्षत्रगोले नक्षत्राणां द्वाविंशत्यधिकसहस्र १०२२ मुक्तमस्ति । तन्मध्य ग्रंथ-कारेण यावनं नक्षत्रगोलं सम्यग् बुध्वा यंत्रोपयोगीनि द्वात्रिंशत् नक्षत्राणि गृहीतानि ।

अध्याय १ श्लोक २१—३८ टीका.

"According to the Greek work, there are 1022 stars described from the celestial globe. The author of this work, after studying the starry globe, has selected only 32 useful stars out of them."

The catalogue of stars referred to in this, appears to be that of Ptolemy, as can be seen from the number of stars which is 1022 and from the date of the writer and that of the commentator (pages 230-231) It seems to have come to this country through the *Muslims*; but it does not appear to have gained currency or came into use.

IDENTIFICATION OF STARS

Now-a-days we do not generally find *Joshis* who can correctly point out at least all the nakṣatras, let alone their junction stars. Colebrooke remarks, "None of the native astronomers, whom I consulted, were able to point out, in the heavens all the asterisms for which they had names." Beruni observes*, "I took great pains in this respect; but I did not come across a single *Joshi* who could point out with his finger the junction stars of all the nakṣatras by merely looking at them." Even in the present times, a *Joshi* who can point out the junction stars can be rarely found. There are several *Joshis* who are unable to point out even the nakṣatras. Once, a Joshi who was very proficient in preparing horoscopes and selecting muhūrtas came accross the author. This *Joshi* did not know that the nakṣatras are seen in the sky in order from West to East; he was under the impression that Aśvinī and other nakṣatras are seen from East to West in the sky. However, we do find some

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people who can recognize most of the nakṣatras. Once the author happened to meet a *Vaidik Brāhmaṇa, named* PHAPHE *from Chaul in the Colaba district.* He knew all the nakṣatras. He recited a verse showing how to find the length of the night by observing the star transiting the meridian. It is given here because of its much usefulness.

Khau	Kha	Jā	Trī	Gu	Chu	Gai/	Cho	Chho	Bhū 1 yuk.
102	112	128	140	153	156	183	196	197	
Chha	Khi	Trī	Ku	Chū	Chhe	Ko	Dvi 2 yuk.		
217	232	240	251	266	277	291			
ṅau	Kha	Chhā	ṅī	Ku	Ghu	Tri 3 yuk.			
305	312	327	345	351	354				
Kha	Ja	Ku	Chū	Ghe	Gho				
12	28	51	64	74	94				

When the nakṣatra Aśvinī is transiting the meridian, the ascendant at the time is 102° (that is to say 12° of Cancer have risen at that time). It thus gives the degrees of the ascendant in the case of 28 nakṣatras. The time should be determined by the useful method of finding the (unknown) time when the ascendant is given. This quotation is based on the numerical code (Page 97) of Āryabhaṭa II, in which the consonants ka, ta, pa, ya, etc. indicate numerals; but in addition to these the vowels a,ā, i,ī,u,ū,e,ai, o,au, also indicate the natural numbers from 1 to 9 and 0 respectively. The *Muhurtasindhu* by Gaṇeśa Daivajña contains* three verses having the same meaning. The numbers indicating ascending degrees have been given in it by usual method, and it has been mentioned there that these are true for a place of Palabha 4, and that for other places these values would vary. From this and also from the fact that the village of Chaul is very near to Nandagaon where Gaṇeśa Daivajña lived, it appears that the quotation 'Khau, kha, ja' etc. and nakṣatras known to the Vaidic Brāhmana mentioned above must have been handed** down traditionally from Gaṇeśa Daivajña.

ORIGIN OF NAKṢATRA SYSTEM

The Chinese, Persians and Arabs had the nakṣatra system in common use among them. Hence, European scholars raise the question whether the nakṣatra system was evolved by the Hindus independently or borrowed from other nations, and attach much importance to it. But I do not consider it very important, because, the decision of the question whether the entire system of mathematical astronomy has been independently developed by the Hindus or borrowed from others does not depend much upon the decision of the question who originated the nakṣatra system. It is not that the knowledge of planetary calculations is bound to follow immediately the knowledge

*They give 263° as the ascending degrees for Spica and 61° for Śata tārakā. If in the above quotation the correct letters be 'gu and ku' in place of 'chu and ku' the agreement will be complete.

**When the Vaidic Brāhmana showed him the nakṣatras, he pointed out the wrong ones as Revatī and Viśākhā. Of these two, the star which he showed him as Revatī was the same as the one shown to J.B. Modak by a good Joshi from Ratnagiri. The same star was identified as Revtī by another good Joshi of Dhulia. One wonders how the same kind of error crept in at three places which are not related with one another. But it is not at all probable that the error could have originated with Gaṇeśa. The author's book, *Jyotirvilāsa*, contains the description of nakṣatras and one can easily learn how to recognize nakṣatras without any one's help.

of nakṣatras, or that the nation that establishes the nakṣatra system can alone establish the theory of planetary movement, or that the nation that borrows the nakṣatra system from another cannot independently discover the planetary theory. Weber, a German scholar, says that the nakṣatra system did not originate with the Hindus. M.Biot, a French scholar emphatically maintains that it was first established by the Chinese and was then borrowed by the Hindus, and Whitney taking his cue from Biot observes that it did not originally belong to the Hindus. Now both Biot and Whitney admit that "The Chinese had been working in the same beaten track, and never developing out of so promising a commencement anything deserving the name of a science, never devising a theory of planetary motions, never even recognising and defining the true character of the cardinal phenomenon of precession.*" Our People have established the nakṣatra system independently. The Chinese may have also established theirs independently. But it is certain that our people did not borrow it from others. This point has already been discussed before (on page 130 of pt. I). It does not require any elaborate treatment here. But let us briefly examine the views of the European scholars. Biot gave a detailed exposition of only the nakṣatra system of the Chinese and that of the corresponding system of the Hindus in a French monthly** journal in 1840, 1845 and 1859 A.D. The gist of his argument is : "Their instruments and their methods of observation, have been closely analogous with those in use among modern astronomers in the West; they have employed a meridian circle and a measure of time, the clepsydra, and have observed meridian-transits, obtaining right ascensions and declinations of the bodies observed. To reduce the errors of their imperfect time-keepers, they long ago selected certain stars near the equator. The stars thus chosen are the *sieu*. Twenty-four of them were fixed upon more than two thousand years before era. (M. Biot says, about B.C. 2357***) The considerations which governed their selection were proximity to the equator of that period, distinct visibility, conspicuous brilliancy, not being demanded for them. To those twenty-four stars four more—Maghā, Viśākhā, Śravaṇa and Bharaṇī—were added in the time of Cheu-Kong B.C. 1100."

BIOT's study of the stars does not contain as much consideration of the Hindu nakṣatras as that of Chinese. WHITNEY has explained and compared in detail all the three systems viz. those of the Chinese, the Arabs and the Hindus. All the three systems have points of resemblance in some respect and divergence in others. On account of this, WHITNEY had to start with the assumption that no one among them can be regarded as the immediate source from which either of the other two has been derived. In spite of this he further remarks, "We would suggest then that a knowledge of the Chinese astronomy, and with it the Chinese system of division of the heavens into 28 mansions was carried into Western Asia at a period not much later than B.C. 1100, and was there adopted by some Western people, either Semitic or Iranian. That in their hands it received a new form, such as adapted it to a ruder and less scientific method of observation, the limiting stars of the mansions being converted into Zodiacal groups or constellations, and in some instances atlered in postion, so as to be brought nearer to the general planetary path of the

*The above views of Biot and Whitney have been cited from pages 180, 200 to 209 and 324, of the translation of the S.S. by Burgess.

***Journal des Savants.*

***This time has been calculated on the assumption that the stars begin from the Kṛttikās. It has not been mentioned in the Chinese works.

ecliptic. That in this changed form, it passed into the keeping of the Hindus—very probably along with the first knowledge of the planets themselves—and entered upon an independent career of history in India ; and that it made its way so far westward as finally to become known and adopted by the Arabs." Our Indian system of nakṣatra has been built up merely on the basis of actual observations taken by the naked eye, whereas the Chinese system had been evolved mainly for helping the observations by instrument. The junction stars selected by us for Rohiṇī, Punarvasu, Maghā, Purva, & Uttara Phalgunī, Svātī, Anurādhā, Jyeṣṭhā, Mūla, Abhijit & Śravaṇa, belong to the first or second magnitudes (rarely of the third magnitude); but instead of taking these, the Chinese have* adopted quite different stars of inferior magnitude for junction stars, because they were useful to them for observation. In short, the Indian system is natural, while the Chinese system is artificial. In these circumstances, when WHITNEY could not assert that the Indians borrowed the nakṣatra system directly from the Chinese, he had to imagine that the system was first passed on to some Semitic or Persian people whose nakṣatra system has left no trace whatsoever, and that by a distortion of the order of progress in nature, the system assumed a still underform and was then transmitted to India. This would suffice to show what WHITNEY's contention is.

The Persians had their own nakṣatra system. But WHITNEY himself observes about it : "There are, as has been noticed above, traces of an Iranian system to be found in the Bundehesh; but this is a work which, although probably not later than the times of Persia's independence under her Sassanian rulers (3rd century A.D.), can pretend to no high antiquity, and no like traces have as yet been pointed out in the earliest Iranian memorial, the Zendavesta." As regards the question whether the Chaldeans had a system of nakṣatra divisions he writes : "*Weber* sees in the *mazzaloth* and *mazzaroth* of the—Scriptures (Job XXXVIII.32; II Kings xxiii.5)—words radically akin with the Arabic *manzil*—indications of the early existence of the system in question among the western Semites, and suspects for it a Chaldean origin: but the allusions appear to us too obscure and equivocal to be relied upon as proof of this, nor is it easy to believe that such a method of the division of the heavens should have prevailed so far to the west and from so ancient a time, without our hearing of it from the Greeks; and especially, if it formed a part of the Chaldean astronomy." Hence, those Semitic or Indians through whom the Chinese system, according to WHITNEY, was introduced in India, were neither Chaldeans nor the Persians; and it is not known if the nakṣatra system was in vogue in any other Semitic or Iranian country, and has continued up to the present time. Hence, it is proved on this basis of WHITNEY's own argument that the intermediaries Semitics or Iranians—suggested by him are not traceable at all.

Up to 1100 B.C. the Chinese had only 24 stars in their system. Hence, WHITNEY and BIOT canot say at all that the Chinese system was imported into India before that time. BIOT says that Abhijit which used to be included in the Hindu nakṣatra system was omitted in 972 A.D. In other words, he suggests that the Chinese system of 28 nakṣatras was in vogue in India till then; but, WHITNEY has himself refuted *Biot's* arguments by pointing out that long before that time, the Hindus had adopted 27 nakṣatras for calculations and that the

*Translation of S.S. by Burgess, P. 324.

Taittirya Saṃhitā mentions only 27 nakṣatras. Hence, the contention of WHITNEY and BIOT, that the Hindus adopted the nakṣatra system from the Chinese, is utterly worthless. Even WEBER observes, "The view that the Hindus borrowed the nakṣatra system from the Chinese cannot be accepted".*

Sir WILLIAM JONES has made a comparative study** of the nakṣatra system of the Arabs and the Hindus ; but WHITNEY remarks, "but it is incomplete and crude, and the inferences drawn therefrom are neither reliable nor important," and Jones has made the comparison not with respect to nakṣatras only but with respect to nakṣatras related to signs; and he has expressed the view that the Hindus have borrowed the system of nakṣatras and rāśis, not from the Greeks, but from the Chaldeans. The opinion of WHITNEY*** has already been stated to be that the Chaldeans had no nakṣatra system. COLEBROOKE has made a detailed comparision**** of the Hindu and Arabian system of nakṣatras and rāśis. But neither Colebrooke nor any other scholar holds that the Hindus adopted the system from the Arabs. Colebrooke †says that it was the Arabs who borrowed it from the Hindus and it is evident from the information given on pages 187 and 188 before. MAX MULLER ‡says that the system of nakṣatras spread into all countries from BABYLONIA. WEBER also observes that the Hindus borrowed it either from the Babyloneans or from the Chaldeans. But MAX MULLER had not made a detailed study of the question and examined its pros & cons; it has been pointed out above ††that, accordin- to Whitney †‡the views of neither of them are acceptable. In short, this disg cussion and the arguments advanced on page 130 of pt. I prove beyond all question that our people have established the nakṣatra system quite independently.

(11) MAHĀPĀTA

The parallel of declination of the sun and moon is called "Mahāpāta". The parallel in declination takes place when the sum of the tropical longitudes of the sun and moon is 6 rāśis (180°) and 12 rāśis (i.e. 360°). The first position is called "*Vyātipāta*" and the second "*Vaidhṛti*". Auspicious ceremonies are disallowed when the parallel in declination occurs. Hence, all works on astronomy deal with its calculation. Gaṇeśa Daivajña has given in his Graha-lāghava the method of this calculation and has also compiled a small work, entitled "Pāta sāraṇī" for easily finding the moments of their occurrence.

So far Gaṇita Skandha (Mathematical branch) has been dealt with ; let us now consider other branches.

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*History of Indian Literature, P. 247.

**Asiatic Researches, Vol. II, 1790.

***Translation of S.S., P. 180.

****Asiatic Researches Vol. IX 1807.

†Algebra, Introduction, P. XXII.

‡Rigveda Vol. IV, Introduction.

††History of Indian Literature, P. 2, Note 2 and p. 247.

†‡Monier Williams had first stated that the nakṣatra system originally belonged to the Hindus. But later on, being dazzled by Whitney's arguments, he reproduced his views and endorsed them. (Indian Wisdom, Page 183 and Note 2) In doing so, he has only shown that he was incapable of independent thinking.

II SAṂHITĀ SKANDHA

(The Saṃhitā Branch)

SUBJECT-MATTER OF SAṂHITĀ

The work which treated in all branches of astronomy used to be called *Saṃhitā*'. But at the time of VARĀHAMIHIRA, the definition had changed. Saṃhitā was then known as the third branch of astronomy, the other two being Gaṇita and Horā. Later on, all the subjects dealt with in the Varāha Saṃhitā very soon dropped away, and the Muhūrta Skandha alone became the third branch. This will be considered later on. The author first describes the contents of the Varāha Saṃhitā, so that the nature of the Saṃhitā branch may be clearly understood. The subjects dealt with are :—The motions of the sun, the moon, Rāhu and other planets and Ketu; and a description of the effects of their movements in the Zodiac, good or evil on the world, the results of the rises of Agastya (Canopus) and Saptarṣi (the Great Bear). These questions are treated in the first 13 chapters. The 14th Chapter is entitled Kūrmādhyāya. It mentions the lordships of nakṣatras over the region falling in the 9 divisions into which India was supposed to be divided. The next question is the nakṣatra "Vyūha" (arrangement of stars) and results accruing from planetary fights and conjunctions. It has already been mentioned that the Saṃhitā does not describe astrological effects on persons; it mentions results, benefic or malefic, affecting nations.

Then follows the study of yearly forecast. It is somewhat similar to the one given now-a-days in almanacs under the heading "Samvatsara phalam". The next chapter is entitled "grahaśṛṅgāṭaka". It gives a forecast of the phenomenon in which all or some planets are seen grouped near the sun or some star in the shape of a bow, a horn, etc. The questions next to follow are the "Parjanya garbha lakṣaṇa" (impregnation of rains) "garbha dhāraṇa" (conception) and 'Varṣaṇa' (raining). It describes in detail how rains are 'conceived' in Mārgaśirṣa and other months and what would be the nature of the rains. Some people study this subject even in the present times, and it is reported that there are some who accurately predict how rains will occur on the basis of their conception. It is stated in this chapter that rainfall should be measured, if it rains, and the method of measuring it is also described. Next are described the results of the moon's conjunctions with Rohiṇī, Svātī, Āṣāḍhā, and Bhādrapadā. Next comes the description of the following phenomena :—sudden rainfall, the description of the plant croton, then comes the question of twilight, the red colour visible in the sky in the morning and evening i.e., 'digdāha' (preternatural redness of the horizon), earthquake, meteors, 'pariveṣa' (a halo), rainbow, *gandharvanagar** (celestial city), perihelion or mock sun, whirlwind',———(Thunderstorm). The next questions dealt with are the prices of grains etc., *Indradhwaja* (a flag raised on Bhādrapad Śukla 12) and *neerajan* (lustration of arms). These are followed by the results of the sight of the bird named 'Khañjan' (wag-tail). Next are described three kinds of disasters namely 'divya' (celestial), 'āntarikṣa' (spatial) and 'bhauma' (terrestrial). Then follows the chapter on Mayūr-citra. The questions which follow are those of interest to kings, e.g. the *Puṣyasnāna*

*A news item had appeared in newspapers about 1887 that the people on a ship sailing on the sea at a distance of some miles from New Holland, witnessed a city in New Holland, in the sky. It seems therefore that the subject of Gandharva-nagar (celestical city) may not be merely fictitious.

(coronation ceremony performed with the moon in puṣya nakṣatra), *Paṭṭa-lakṣana*, (the characteristics of the crown), the *Khaḍga lakṣana* (the characteristics of the sword). The next chapter relates to *Vāstu* (building). This contains a very extensive description. It provides useful information regarding the choice of site and wood for the house and the method of building houses for different purposes. UTPALA has given five charts in the commentary on the work. The next chapter, entitled *Udakārgala*, mainly describes the art of water-finding and sets forth incidentally some ideas on geology. It is said that even now there are people who can direct one to a place, where water would be obtained after digging. Next comes the chapter on *Vṛkṣāyurveda* (the therapy of trees), which contains some sound hints on Botany. Next comes the chapter on *Prāsādalakṣaṇa* (characteristics of palaces), the next chapter headed *Vajralepa*, treats of the method of manufacturing some kind of lime. It is said to have been revealed by MAYA. Further on comes the question of the idols of deities (that is, the method of moulding etc). Then comes the question of *Vāstu pratiṣṭhā* (the consecration of buildings). Further on are discussed the characteristics of cows, dogs, cocks, tortoises, goats, men and women. These are followed by the question of testing the chowrie and the sceptre, some ideas on erotics, testing of jewels like diamonds, pearls, ruby etc. Then are discussed the questions regarding lights, cleaning of teeth, omens. These are followed by the results, auspicious or otherwise, of the cries of dogs and jackals. Next are considered the questions regarding dear, elephants etc. After this comes the description of the effects of tithi, nakṣatra and Karaṇa and those of the transiting planets.

The author has not seen many of Saṃhitā works. However, all the earlier Saṃhitā works such as those by Garga and others, who lived before Varāha, appear to have dealt with these very subjects or some of them. The selection of auspicious time (muhūrta) for ceremonies like marriage etc. appears to be a subject dealt with by saṃhitā works. But because Varāha had compiled separate work on pilgrimage and marriage, it appears that these subjects have not been included in this work.

Varāha has stated at several places that particular subjects have been treated as taught by particular *Riṣis*. The following names of *Riṣis* have occured in this connection.—Garga, Parāśara, Asita, Devala, Vṛddhagarga, Kaśyapa, Bhṛgu, Vasiṣtha, Bṛhaspati, Manu, Maya, Sārasvata* and Riṣiputra. It appears, therefore, that so many saṃhitās were extant at the time of Varāha. There may have existed even more since Varāha has at some places remarked "anyān bahūn" (meaning 'many others'). The commentator has cited not only the views of the above authors in the commentary but has added many more from other authors also. Among these we find the quotations from Vyāsa, Bhānubhatta, Viṣṇugupta, Viṣṇucandra, Yavana, Roma, Siddhāsana Nandī, Nagnajit and others and also some from the work Bhadrabāhu. Some of these authors may have flourished before Varāha and some after him. The chapter on Vāstu (house building) contains quotations from Kiraṇākhya Tantra, as also from Maya.

The above list of subjects will show that it includes several sciences of the present day, which are related not only to astronomy but to other celestial phenomena also, and they include several natural phenomena relating to the

*The name of Sārasvata occurs only in the chapter on Udakārgala and that of Maya in the chapter on Vastu and similar subjects.

earth. Besides these they treat in questions bearing on every-day life. Some of these subjects had been considered long before Varāha's time and some others appear to have been under consideration from ancient times right up to his days. Varāha has recorded some views of his own at several places. Thus after citing the chapter on Udakārgala, as taught by the sage Sārasvata, he has given much information with the prefatory words "I shall now quote the views of human beings". If the subjects in the Varāha Saṃhitā had continued to be explored even later, the results would have proved very useful according to the author's remarks before (page 80). But no single work or even a number of works was ever produced in later years which treated in all or most of the subjects dealt with in Varāha's Saṃhitā. The work *Muhūrta-tatva* has discussed almost all the subjects in brief, and the work *Jyotiṣadarpaṇa* contains a chapter on the subject of grahachāra' (movements of planets). But it would not be wrong to say that these subjects were consigned to oblivion after Varāha; some stray thoughts on two or three questions like 'garbhāvali.' (conception of rain waters) are found in some works or in miscellaneous writings and they are even now taken into consideration by some people; but very few of these writings are important. The chapter on Vāstu (building) is given by all works on muhūrta in the present times and it does contain some useful information; however, their original object has been mostly forgotten and now-a-days no one cares much to follow the method explained even in the present-day works while who would care to observe a rule* which says, for instance, that the house would be auspicious or inauspicious according to the remainder obtained by dividing the sum of the length and breadth by a certain number. But while rejecting such rules, one is even disposed not to consider and utilize useful information given in such works.

MUHURTA WORKS

Certain rules have been framed to show what moments prove beneficial if selected for performing the sanctifying ceremony of impregnation, for starting on journeys and for several other functions concerning every day life; and the moments thus selected are technically known as 'muhurtas'. Formerly, the consideration of such muhūrtas formed part of the saṃhitā works; but later on all other subjects in the saṃhitā lost their importance and ceased to exist, while 'Muhūrta' became their most dominant feature. Later, still, the works related to the selection of Muhūrtas came to be styled 'Muhurta-works'.

THEIR CONTENTS

A muhūrta work commonly contains the following subjects :—

The muhūrta work usually contains a general chapter called the 'tyājya prakaraṇa' (the chapter of taboos). It mentions the tithis, nakṣatras etc. which are prohibited for any auspicious ceremony. Next comes a general description of the nature, auspicious or otherwise, of tithi, day of the week, nakṣatra, yoga, saṃkrānti etc. Next come the muhūrtas favourable for fifteen sacraments such as impregnation and other sanctifying ceremonies,

*Some rules have been framed regarding the length and breadth corresponding to the auspicious and inauspicious nature of nakṣatras, and much skill appears to have been used in it. The chapters on building in Muhūrta Mārtanda, deal with areas and similar matters. It was once explained to a Joshi but it was apparent that very few Joshis understand the subject. How can those who do not know even the A B C of geometry and mensuration understand the subject.

It includes an important and lengthy chapter on the horoscopic affinity of the prospective bride and bridegroom. In addition to this, it contains chapter on miscellaneous subjects like buildings, pilgrimage (travel), coronation etc. Some works deal with the "pacification-ceremony"* in connection with births under malefic nakṣatras in the chapter on nakṣatras.

The work *Ratnamālā* by ŚRĪPATI treats in these very subjects and nothing else, which have been mentioned so far, as forming the contents of the Muhūrta works. Śrīpati has only not named this work as a mūhurta work. Later on people actually began to name such works as Muhūrta Mārtanda Śrīpati's work has been compiled with the help of Lalla's Ratnakośa. It appears that even Lalla's work did not contain any subjects other than muhūrtas. No other work like Varāha's Saṃhitā appears to have been ever compiled after Varāha. It shows, therefore, that 'Muhūrta' alone constituted the third branch (skandha) of astronomy from about Śaka 500 to 600.

BASIS OF GOOD OR EVIL EFFECT

The auspicious or inauspicious nature of nakṣatras in regard to the performance of rites is based on such considerations as the names of nakṣatras and their controlling deities. The horse and other imaginary categories (yoni)** assigned to Aśvinī and other nakṣatras, the imaginary terms cara (movable), sthira (fixed) etc. the animals like ram etc. suggested by names like Meśa (a ram) etc. given to signs, Mars and other lords of signs, Nanda and other names given to the tithis, lords of tithis and similar other things. For example the performance of a rite to ensure 'fixity' or stability under the influence of a 'movable' nakṣatra is regarded as inauspicious: if the birth nakṣatras of the bride and the bridegroom be Rohiṇī and Uttarāṣāḍhā respectively, then the union would prove unfortunate because these (nakṣatras) are regarded as coming under the categories of snake and mongoose who are natural enemies and so on.

NEED OF MUHŪRTAS

These muhūrtas have intimate association with every day affairs of life and it will be seen from the discussion at several places in Part I that it has continued to exist from times immemorial. In the present times marriages cannot be performed at all without muhūrtas. Ceremonies like the foundation of the house, entering a newly built house for the first time, sowing the corn and reaping the harvest, etc. cannot generally be undertaken without muhūrtas, and there are many people who undertake many such affairs of practical life only after consulting the muhūrtas. It is not the followers of Vedic religion alone, who are guided by muhūrtas; even the Liṅgāyats and Jains cannot get on for a moment without the muhūrtas. Even the Parsees and the Mohamedans seek the guidance of muhūrtas. The need of muhūrtas has been one of the main causes for developing what little knowledge of astronomy had been acquired by our people and for keeping it alive till to-day.

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*The selection of muhūrta very often calls for the consideration of the birth-horoscope or horoscope for the moment in question, or both. The subject of horoscopes is discussed later on. Even the question of "Sadvargas" is involved in the selection of the muhūrtas for marriages etc.

**Madhava, the Commentator of Ratnamālā observes in the chapter on nakṣatras—these yonis, as originally devised by 'āgamas' were introduced by former authors for the settlement of marriages etc, they do not exist in reality.

HISTORY OF MUHŪRTA WORKS

The review of this branch will be concluded after giving a brief history of the muhūrta works and their authors. Even the following short account would show that *numerous works on muhūrta* have been compiled so far. The author mentions here only those about which he knows something either directly or through tradition.

RATNAKOŚA (about Śaka 560)

This is a work compiled by Lalla. The author has not seen it. Śrīpati has however, compiled his work Ratnamālā on the basis of this work, which shows that it may have been like the present-day muhūrta work.

RATNAMĀLĀ (about Śaka 961)

This was compiled by Śrīpati. It contains only those subjects* which have been mentioned above as belonging to a muhūrta work. It has a commentary by Mādhava. The date of Mādhava is Śaka 1185. He has cited passages from many other works. The author mentions here the names of those muhūrta works and their compilers which have not been referred to before or even later on. The names of the authors are **:—

Śrīdhara, Brahmaśambhu, Yogeśwarācārya. (The last two names have occurred in the chapter on 'Vāstu' (building) The names of works are :— Bhāskara, Vyavahāra Bhimaparākrama, Daivajña Vallabha, Ācāra Sāra. This may be a work devoted to ritual, Trivikrama Śata, Keśava Vyavahāra, Tilak Vyavahāra, Yoga Yātrā, Vidyādhārī Vilāsa, Vivāha Paṭala, Viśvakarma Śāstra (This name has occurred in the chapter on 'Vāstu') In addition to these, quotations have been taken also from such Jātaka-works as Laghujātaka Yavanajātaka, Vṛddhajātaka from Narapati Jayācārya, work on omens and from Vidvajjana-Vallabha a work on horāry astrology.

In the chapter on the 'days of the week' he remarks, "in this Ānandapura, the length of the shadow on the day of the equinox is 5·20 and the hypotenuse is 13·8", which shows that his place of residence may be Ānand Pur : and this may be situated some where in latitude 24°.

RĀJAMĀRTANDA

This is a work by BHOJA ; its date may be about Śaka 964.

VIVĀHA VṚNDĀVANA (*Circa* S. 1165)

An astronomer named Keśava compiled this work on 'marriage' which is usually the subject of a chapter in muhūrta works. This work has already been commented upon (on pages 127 and 194). The name Keśava occurs in Mādhava's commentary on Ratnamālā written in Śaka 1185. This

*The commentator, however, remarks : "The author discourses with a view to expounding the subjects met with in the Saṃhitā works".

**Mādhava has incidentally cited passages from works related to other subjects also. The author mentions the works of their authors as they may prove useful :—Nyāya Kiraṇāvalī ; Kaṇāda Sūtras ; Praśastakar Bhāṣya ; Bhāṣyottara Purāṇa ; Matsya Purāṇa ; Śhiva Rahasya ; Baudhāyana, Gṛhāstha Dharma Samuccaya ; Smṛti Mañjarī ; Saura Dharmottara, Skanda Purāṇa ; Viṣṇu Dharmottara ; Viśvarūpa ; Vijñyāneśvar ; Purāṇasamuccaya Vāgbata ; Yājña-Valkya Smṛti ; Durga Siṃha ; Garuḍa Purāṇa ; Viśvādarśa Bhāṣya ; Vaidyanighanṭa ; Suśrutacikitsita.

leads to the inference that the selfsame Keśava may have been the author of Vivāha Vṛndāvana and this lends support to the view that his date was about S. 1165. A work entitled, Keśava Vyavahāra has been mentioned in Mādhava's commentary, which also may have been written by this Keśava.

VIVĀHAPATALA (by Śaraṅgadhara)

This is a Muhūrta work relating to the question of marriage. It refers to *Hemādri* and *Mādhava*, and it is referred to in commentary on the work Vivāha Paṭala by Pitāmbara, written in S. 1446. The date of this work may therefore be about S. 1400. It seems that it was also entitled 'Sāra Samuccaya.' The commentary on Muhūrtatatva by Gaṇeśa (circa. 1450) mentions Śāraṅgadhara and Sāra Samuccaya. This also shows that the date of Śraṅgadhara could not have been later than S. 1400. The author mentions here the names of some of the authors and works that have not been considered before :—

Authors :—HARI, GADADHARA, MUKUNDA, BHĀRGAVA, PAVANEŚVARA Lakṣmīdharabhat. Works :—Muktāvali, Lakṣmīdhara Paṭala, Gadādhara Paṭala, Ratnojvala Saṃhitā. All these works and authors were probably concerned with Muhūrta-Branch of astronomy.

MUHŪRTA TATVA

It was compiled by Keśava, a resident of the village of Nandigrāma. Hence his date may be about Śaka 1420. The author not only deals with all the questions mentioned as belonging to muhūrta works, but adds the remark, "here ends the part on muhūrta, and that on saṃhitā begins", and briefly discusses a good many questions from Varāha Saṃhitā, like the movements of planets, planetary fights etc. It does not however appear that any one in his time had been making any use of such information. This work contains a chapter on 'ships' which is a special feature. It follows the chapter on travel, and gives advice regarding auspicious times for ship-building, for landing, for landing ships, and for travelling in ships. No other work on 'muhūrta' appears to have dealt with this question. The commentary on the work does not contain any quotations from previous writers taken in support of any statement. The words *nāl* (bow) *sukān* (helm) have been used in the verses. Upon this, Ganeśa Daivajña the commentator observes, "these popular terms have been admitted into the original, as other suitable terms are not found in the dictionaries." It appears that he may have been a resident of a place on the sea coast, and as seafaring fishermen used to consult him for muhūrta he appears to have compiled this chapter anew. *Nāvapradīpa* is another independent work* to his credit. The work Muhūrta Tatva is at present in use. The author's son GANEŚA Daivajña has written a commentary on it. Its date appears to be about Śaka 1450. It has been printed. The author mentions from it the names of such works and authors as have not been referred to before.

Authors :—VASANTA RĀJA, BHUPĀLA, NṚSIMHA.

Works :—Vivāha Patala, Jyotiḥsāra, Śānti Patala, Saṃhitā dipaka Saṇgraha, Muhūrtasaṇgraha, Arṇava, Vidhiratna, Śrīdharīya, Jyotiṣārka, Bhupāla vallabha, Jyotiş Prakāśa**.

*Deccan College Library, No. 332 of 1882-83.

**Names of books relating to other subjects are :—Bhāgavata, Aśvalāyana Gṛhya kārikā, Padmapurāṇa, Smṛtyarthasāra, Smṛti Rātnavalī, Naiṣadha Kāvya and Nṛsiṃha Prabandha.

VIVĀHA PATALA (by Pitāmbara)

This work, compiled in Śaka 1444, consists of 52 verses. The author himself has written on it an exhaustive commentary entitled "Nirṇayāmṛta". in Saka 1446. The name of Pitāmbara's father was RĀMA and that of his grand father, JAGANNĀTHA. He was a Gauḍa Brāhmaṇa residing at STAMBHA-TĪRTHA (Khambayat, Cambay) near the mouth of the river Mahi. The author mentions here such names of authors and aṣtronomical works as have been in the commentary***, but not noticed in his account so far.

Authors]—PRABHĀKARA, VAIDYANĀTHA, MADHUSŪDANA, VASANTARAJA, ŚUREŚVARA, VĀMANA, BHAGURI, ĀŚĀDHARA, ANANTA BHATTA, MADANA, BHUPĀLA VALLABHA.

Works :—Cintāmaṇi, Vivāha Kaumudī, Vivāha Paṭala by Vaidyanātha, Vyavahāra Tatvaśata, Rūpa Nārāyana Grantha, Jyotiṣa Prakāśa, Saṃhitā Pradīpa, Cūḍā ratna, Saṃhitāsāra, Mauñjī Patala, Dharmatatvakalānidhi Saṇgraha, Trivikrama Bhāṣya, Jyotissāgara, Jyotirnibandha, Sandehadosausadha, Sajjana Vallabha, Jyotiṣa Cintāmaṇi, Jyotirvivaraṇa, Jyotirviveka, Phalapradīpa, Goraja Paṭala and Kāla Viveka. All these works and authors were mainly concerned with the Muhūrta branch. In addition to these, the names of Tājika Tilaka and Sāmudra Tilaka have also occurred in the works. As for works on other subjects, a dictionary entitled *Śabda Ratnākara* has also been mentioned.

JYOTIṢA DARPAṆA

This work was compiled in Śaka 1479, by a Jyotiṣī named KANCH PALLU. It is written partly in prose and partly in verse form. The copy of the work that happened to be seen by the author was incomplete. It appears to deal first with the question of Grahacāra, (movements of planets) and this was probably followed by the chapter on Muhūrta. The author was a Brāhmana, belonging to the Kanva branch of the Vatsa gotra. His place of residence was a village named Kondapalli. He has given the length of the equinoctial shadow of the place as 3-36 and *deśāntara* (longitude) as 40 East. He claims that his almanac is in use up to Kanchi. The god Nṛsiṃha at *Nargiri* was his family deity. He has referred to a work named *Pailu Bhatiya.*

MUHŪRTA MĀRTAṆḌA (Śaka 1493)

The account of *Nārāyaṇa*, its author, has already been given (on page 150). He seems to have studied under the care of his father. He has himself written a commentary on his own work. This work is very much in popular use at the present time. This consists of 160 verses in different metres. Many people study the work as if it were a poem of literary merit. The work is confined only to those subjects which come within the jurisdiction of muhūrta works. The author, however, remarks at the beginning of the commentary : "Desirous of compiling a saṃhitā work the author writes"—The commentary cites passages from several writers. The names of authors and muhūrta works which have not been noticed before are mentioned below :

Authors :—Gopiraj, Menganath, Mhalugi (These names occur in the chapter on Vāstu).

***The commentary on Muhūrtatatva belongs to about the same date as this commentary'. But its accurate date is not known. Hence, the names of works etc. mentioned under the former have been repeated here, wherever they occur.

Works :—Udvāhatatva, Muhūrta Darpaṇa, Kaśyapa Paṭala, Saṃhitā Sarāvalī, Vyavahārasāra Śilpaśāstra, Bṛhad Vāstupaddhati, Samarāṅgana Vyavahāra Sārasvata, (the last six out of these names occur in Vāstuprakaraṇa) Ratnāvalī : the names of Sphuṭakaraṇa (Maths) and Jāta Kottama (astrology) are the additional names* which occur in the commentary. This work has been published together with commentary.

TOḌARĀNANDA

This voluminous work by Nilkantha belongs to Śaka 1509 (Circa). The author has seen a portion of the work in which are cited a number of passages from the following authors and works. The authors are :—Caṇḍeśvara, Yavaneśvara, Durgāditya. And the works are :—Daivajña Manohara, Vyavahārochaya, Kalpalatā. (See Page 148).

MUHŪRTA CINTĀMAṆI

Ramabhata, a Jyotiṣī, compiled this work in Śaka 1522. Some account of this Ramabhata has already appeared before (Page 151). It contains the same subjects as are usually found in muhūrta works. Its influence is widespread. It has a commentary named Pramitākṣarā by the author himself and another named Pīyūṣadhārā by his nephew GOVINDA. Both of them have been printed. The names of astronomical works, occurring in the commentary on Piyūṣadhārā (Śaka 1525) and not referred to before, are :—Jaganmohana, Jyotiṣa Ratna Saṃgrha.

MUHŪRTA CŪḌAMAṆI

A Jyotiṣī named Shiva compiled this work. The family history of Shiva has already been given (Page 157). The date of this work may have been about Śaka 1540.

MUHŪRTA KALPADRUMA

Vithal Dīkṣita, of Kṛṣṇātri gotra, wrote this work. It bears a commentary named Muhūrta Kalpa-Druma-Mañjarī, by the writer himself, written in Śaka 1549.

MUHŪRTA MĀLĀ

This work was written at Varanashi by Jyotiṣī Raghunātha in Vikrama Saṃvat 1717 (i.e. Śaka 1582 ; 1660 A.D.). Raghunātha was a Gitpavana Brāhmaṇa of Śāṇḍilya gotra. His ancestors used to reside at PALSHET south of Dabhol, in South Konkan. His grand father's name was Keśava. His father Nṛsiṃha went to Varanasi and established himself there. He had the patronage of Emperor Akbar. Raghunātha received the title of Jyotirvitsarasa, when Akbar captured the fort of Aseri. The writer has given the following account in a verse :

*Names of authors and works relating to other subjects :—

Brahmapurāṇa, Kātyāyana Gṛhya Kārikā, Kātyāyana Gṛhya Harihara Miśra Vyākhyā, Kālanirṇayadīpikā savivaraṇa ; Mārkaṇḍeya Purāṇa, Dhananjaya kośa (Dictionary), Anekārtha Dhvani mañjarī (Dict.) Smṛti Sārāvali, Shulba Sūtra, Halāyudha Kośa, Dharma Pradīpa, Tīrtha Khaṇḍa, Pitṛ khaṇḍa, Preta Mañjarī, Āditya Purāṇa.

जित्वा दाराशाहं सूजाशाहं मुरादशाहं च ।।
अवरंगजेबशाहे शासत्यवनीं ममायमुद्योगः ।।

"I have undertaken this work when Emperor Aurangzeb is ruling the earth, after conquering Dara, Shuja and Murad".

This work has been printed.

MUHŪRTA DĪPAKA

Jyotiṣi MAHĀDEVA compiled this work in Śaka 1583. Mahādeva was a resident of Bhuj (Cutch). His father's name was Kanhaji. He has extolled his father by calling him "*Raivataka* Rāja Pūjita Pada" (i.e. one whose feet were worshipped by the king of Raivataka). In enumerating his contemplated works he mentions *inter alia* Vyavahāra Prakāśa and Rāja Vallabha, which have not been noticed so far. This work is available in printed form. It bears a commentary by the author himself. According to AUFRECHT, the commentary contains the names of following works, not referred to before :—Amṛta Kumbha, Lakṣana Samuccaya, and Sāra Saṃgraha.

MUHŪRTA GAṆAPATI

A Jyotiṣi named Gaṇapati, wrote this work in Vikrama Samvat 1742 (Śaka 1607). In his account he observes :—

गौडोर्वीशशिरोविभूषणमणिर्गोपालदासोऽभवन्
मांधातेत्यभिरक्षिताद्धग्रलभते ख्याति स दिल्ली* श्वरात् ।।
तत्पुत्रो विजयी मनोहरनृपो विद्योतते सर्वदा ।।

This king Manohara, has been alluded by the author as 'Gauḍānvaya Kumudagaṇānāndicandra". The work was compiled as desired by his son YUVARĀJA RĀMA. The author was an Audicya Gurjara Brāhmaṇa and belonging to Bharadvāja gotra. His surname appears to have been Rāvala. The names of his ancestors from the father upwards were : Harisaṅkara, Rāmadāsa, Yaśodhara and Brahmarṣi respectively.

This work has been printed.

MUHŪRTA SINDHU

GANGADHAR SHASTRI DATAR (Born in Śaka 1744, died in Śaka 1810) wrote a Sanskrit-Marathi work in Śaka 1805, entitled "Muhūrta Sindhu". This work has dealt with Muhūrtas in detail, discussing their exceptions and counter-exceptions and quoting chapter and verse from 38 different works in support of his statements. The work has been printed.

Some more information about works on Saṃhitā and Muhūrta are given below. These were obtained after 472 pages of Dixit's original work were printed.

VIDVAJJANA VALLABHA

The following information about this work is available from the list of

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*This emperor must be Aurangzeb.

books in the Maharashtra Government **Library, Tanjore :—

This work was compiled by BHOJA (which means that it belongs to Śaka 964 Circa). It contains the following chapters :—

(1) Gain and Loss (2) Arrival and Departure of enemies. (3) Departure and Return. (4) Return of emissaries. (5) Travel. (6) Success and Failure (7) Truce. (8) Places of refuge. (9) Bondage and Freedom. (10) Patients (11) Birth of a daughter. (12) Conception. (13) Birth. (14) Rainfall (15) Buried treasure. (16) (incomplete). (17) Miscellaneous. (18) Anxiety.

It consists of about 185 verses in all. One wonders why Bhoja compiled another work, when Rāja Mārtaṇḍa a work on Saṃhitā branch, was already compiled. However,even if this work be attributed to some one else, there is no doubt that it belongs to a date earlier than Śaka 1185, because its name occurs in Mādhava's commentary on Ratnamālā.

ADBHUTA SĀGARA

MAHĀRĀJA BALLĀLSEN, the king of Mithilā maṇḍal, compiled this work. Ballālsen ascended the throne in Śaka 1082 and it is stated in the work that it was written by him in Śaka 1090. The author has not seen if it contains any subject other than those in Varāha Saṃhitā. However, Sudhākara writes that the work is worth seeing. The chapters in it are called āvarta'. It is stated in the chapter on eclipse that "if a hole is seen in the disc of the sun, without there being a transit of Venus or Mercury, it forebodes an attack by foreigners". It shows that the "Piercing of the sun by Mercury and Venus" was known to them : and the appearance of holes in the sun's disc in the absence of this phenomenon is nothing but the appearance of sun spots. The author of the text remarks, "I have properly noted the occurrence of ayanāṃśas, (and I have determined the ayanāṃśa from them)". This indicates his love of research. The work mentions a number of other works and writers, such as VASANTA RĀJA and PRABHĀKARA among authors and *Vaṭakanikā,* Viṣṇu Dharmottara and *Bhāgvata* among the works.

VYĀVAHĀRA PRADĪPA

This is a good work on the Muhūrta branch of Saṃhitā by PADMANĀBHA. Padmanābha was the son of Kṛṣṇadāsa, grand son of Gaṅgādāsa and great grand son of Śivadāsa, a Brāhmana resident of the town named Yamunāpura. His work contains quotations from such works as Bhima Parākrama, Śrīpati's Ratnamālā, Dīpikā Rupa Nārāyaṇa, Rāja Mārtaṇḍa, Sāra Sāgara, Ratnāvali, Jyotiṣtantra (a work on astronomy), Vyāvahāra Caṇḍeśwara and Muktāvali. SUDHĀKARA remarks that this Padmanābha is the same as the one mentioned by Bhāskara as a writer on Algebra. But it has already been pointed out before (Page 95) that Padmanābha, the writer on Algebra, lived before Śaka 700; and the works Vyavahāra Pradīpa refers to Ratnamālā and Rāja Mārtaṇḍa. It was evidently written sometime after Śaka 964. Padmanābha's work also gives quotations from the Sūrya-Siddhānta, Varāha Saṃhitā and other works,

**Vyankoji (Ekoji), brother of Shivaji and his descendants ruled over Tanjore. A very fine library had been maintained by these kings in the royal palace at Tanjore. A catalogue of the books, prepared by A.C. Burnell under the orders of the Madras Government was printed in 1879 A.D. King Tulaji, a descendant of the family, was on the throne from 1765 to 1788 A.D. The Library contains books written by him or under his direction. Probably this collection of books was mainly originated in his regime.

and they are found in the modern S.S. and other works. But the Siddhānta Śiromaṇi *gives 4 verses, of which one is Padmanābha's own verse and the remaining three have been quoted by him as from each of the works Śaunak Saṃhitā, Vasiṣṭha Saṃhitā and Jyotiṣtantra. This indicates, according to Sudhākara, that Bhāskara must have borrowed these verses from the respective works. But from the nature of the verses, it is felt that Padmanābha's statement is itself unreliable and it is the author's opinion that he lived after Śaka 1072.

JYOTIRVIDĀBHARAṆA

This is a work on Muhūrta. It is stated in it that it was written in *Kali elapsed year* **3068**, by KĀLIDĀSA who was the author of Raghuvaṃśam and other works. But it is false. (see page 75). Accordirg to this work, the declinations of the sun and the moon become equal when the third part of *Aindra yoga* has passed. From this his date comes to about Śaka 1164. If Kālidāsa is at all the name of its author, he must have been different from the author of the *Raghuvamṣam*.

JYOTIRNIBANDHA

This Muhūrta work meant for religious purposes was compiled by ŚIVADĀSA. As it is referred to in the commentary on Vivāha-Paṭala by Pitāmbara, it appears to belong to a date earlier than Śaka 1446.

There are several additional Muhūrta works about the dates of wihch only something is known.

ŚAKUNA

This also is a part of Saṃhiā branch. There is a very ancient work named Narapatijayacaryā on the subject, in Vikrama Samvat 1232 (i.e. Śaka 1097). NARAPATI wrote this work at *Anhil-Paṭṭan*. Narapati seems to have been a Jain. His father ĀMRADEVA, was a very learned man and a resident of DHĀRĀ. This book mainly deals with good or evil results affecting kings corresponding to a 'svara' (breath). The author has stated the number of verses in it to be 4500. This work appears to have been known also as *Svarodaya* and *Sāroddhāra*. The works consulted by the author have been enumerated, thus in the beginning.

श्रुत्वादौ यामलान् सप्त तथा युद्धजयार्णवं ।। कौमारीकौशलं चैव योगिनां योगसंभवं ।। ४ ।।
रक्तत्रिमूर्तिकं (रक्ताक्षं तंत्रमुख्यं) च स्वरसिहं स्वरार्णवं ।। भूबलं गारुडं नाम लंपटं
स्वरभैरबं ।। ५ ।। तंत्रवलंच तार्ख्यं (तंत्रं रुणांगं दाक्षं) च सिद्धांतं जयपद्धति ।।
पुस्तकेंद्रं पटौकश्रीदर्पणं ज्योतिषार्णाबं ।। ६ ।। सारोद्धारं प्रवक्ष्यामि

"I compile the work Sāroddāhra, after studying the following works :—

The seven Yāmalas, Yuddhajayārṇava, Kaumārī Kauśala, Yogasambhava of the yogīs, Rakta Trimūrtikam, Svara Siṃha, Svarārṇava, Bhubala, Gāruḍa, Lampaṭa. Svarabhairava, Tantravala, Tākhya (Runāṅga, Dākṣa). The Siddhanta named Jayapaddhati : Patauka Śrī Darpaṇa and Jyotiṣārṇava."

*"Tuṣyantu"-5th verse, from Madhyamādhikāra, in Ganitadhyāya, "Divyaṃ Jnyā-"-9th verse from Chedaka, in Golādhyaya. "Yo veda........"-8th verse, from Gola Asaṃkrā........"6th verse, Madhyamādhikāra.

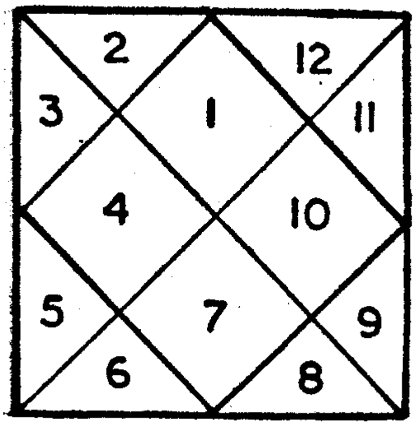
In addition to this, the names of the authors, VASANTA RĀJA and the works Gaṇitasāra and Cūḍamaṇi *also occur in it. It, therefore, shows that all these works belong to a date earlier than Śaka 1097. There is a commentary named Jayalakṣmī by Harivaṃśa on the Narapati Jayacaryā ; similarly, Narahari, Bhūdhar and Ramanath have also written commentaries **on it. Rama Vajpai, ***son of Sūryadas, a resident of the holy city of Naimiṣa, has compiled a work, named Samara Sāra on the science of 'svara' His brother Bharat has written a commentary on it. This 'Svara-śāstra' is mainly based on the nature of the air breathed through the nostrils. There are several other works on the subject.

III—*JĀTAKA SKANDHA*

(Natal Astrology)

DEFINITION

That science is called *Horā Śāstra* or *Jātaka* (Natal Astrology) which decides what happiness or misery would fall to the lot of the native during his life, from a consideration of the planets in the ascendant at birth or in different positions from the ascendant or in the positions in relation to the moon's sign at birth, or from a consideration of the tithi, nakṣatra etc. at the time of birth or, in short, from the planetary positions at the time of birth. There is a subsection of astrology which is known as the 'Tājika'. It will be discussed later on. The author first describes the science of astrology in brief.



The diagram drawn in the margin is known as *Kuṇḍalī* (Horoscope). The number indicating the rising sign† (ascendant) at birth is noted in the place numbered one(1).This house is always termed the 'first house', no matter what sign out of the twelve occupies it. The places marked 2, 3, etc. in the horoscope are respectively called the 'second house', third house' and so on, and the planets are posited in the respective houses according to the signs they occupy at birth. These twelve houses are successively termed : body wealth, brothers, friends, sons, enemies, wife,' death, religion, occupation gains and expenses. All matters denoted by these terms, as also other matters associated with them are considered on the basis of the planets occupying the signs in the houses and the aspectual and other relations of other planets to

*Rāja Mārtaṇḍa refers to Cūdamaṇi, which shows that the Muhūrta work was written sometime before Śaka 964.

**This information about the work Narapatijayacaryā has been collected from five different books. Narapati states that he has described the complete system of Mathematical astronomy in his work, Jyotiṣa Kalpa Vṛkṣa.

***This Rama observes that he has a Karaṇa work to his credit. He has similarly written a book on the subject, "Kuṇḍa", (i.e. a bowel shaped holy vessel) ; it belongs to Saka 1371.

†The Ascendant at birth means that sign which is rising on the horizon at the time of birth. The birth horoscope should be held in a plane perpendicular to the earth and passing through the plane of the ecliptic. The house indicating the ascendant should be held towards the East and the 7th house towards the West. That will represent the positions of planets in the sky at the desired moment. The upper half is visible and the lower half is 'set'. The tenth house comes just below the zenith and the 4th house in the nadir.

those houses. For example, all problems relating to wife are judged from the seventh house. These twelve houses are known by other names also. It is not that these are only 12 things in life which make a man happy or unhappy. But the names given to the houses serve as general keywords. The problem under consideration is supposed to fall within the perview of one of the twelve houses. For example, all problems related to the king are to be considered from the tenth house. Most of the questions are to be judged from the horoscope of birth. On rare occcasions, they are considered on the basis of the "rāśikuṇḍali", that is that horoscope, in which the sign occupied by the moon at birth is placed in the first house. Other types of horoscopes have also been devised. It has been assumed that a particular sign is the 'own-house' or the 'Uchcha' (i.e. sign of exaltation) of a particular planet. Cancer and Leo are respectively under the ownership of the sun and the moon. The signs on either side of these, viz. Gemini and Virgo are of Mercury. The next signs on either side, viz. Taurus and Libra are the own houses of Venus. Those beyond the two, viz. Aries and Scorpio are owned by Mars. Those still beyond viz. Pisces and Sagittarius are owned by Jupiter ; and lastly, Capricon and Aquarius have been assumedto be the own houses of Saturn. The signs of exaltation are not governed by any order. The mathematical positions of 'Uchcha' (aphelia) are quite different. For instance, the sun's mathematical positions of 'Uchcha' (apogee) at the present time is nirayaṇa Mithuna (Gemini) and sāyana Karka (Cancer). But in astrology, Meṣa is the 'Uchcha' of the sun. It is not known on what principle these Uchchas have been determined. The sāyana aphelia have got considerable motion. Hence some people maintain that the points of exaltation in astrology were determined at a time when they actually coincided with the orbital 'Uchchas' or aphelia of the planets according to the sāyana measure. The followers of nirayaṇa system will never accept the view. But even if the theory is considered plausible, it is hardly acceptable from the chronological point of view. The sun's apogee was in sāyana Aries between 4100 B.S. and 2300 B.S. Circa. The "Uchcha" of Mars in astrology is Capricon, while its orbital uchcha (aphelion) was in sāyana Capricorn between the years 11500 B.S. and 9700 B.S. and never later than that. But when it is extremely doubtful whether the science of astrology had come into being at all in such ancient times, how can the theory be regarded as even plausible ? There are some persons who believe that Meṣa and other terms existed in such ancient times, that the planets were known, and that over and above this astronomy and astrology had reached a very high level. But the author does not consider it possible. Leaving this question aside, one finds that friendship and enmity among the planets have also been postulated. It is further assumed that when planets occupy their own signs or signs of exaltation they produce a highly benefic effect, if they are in their fall or in houses owned by their enemies. The effect is different and a still different effect follows if the planets are retrograde, and the planets show benefic or evil effects or more or less powerul effects according to their aspects to other house. Some of the ideas appear to have been based on the common experiences in practical life but there are others that defy explanation. Again not all authors are unanimous regarding the results ; one comes across divergent views on many a point. At present European astrologers read the horoscopes on the basis of the sāyana signs. MADHAVARAO BRAHMAJI, Jeevanrao Tryambakrao CHITNIS *and others claim that the interpretations of planets given in our ancient works can be verified much better on the basis of the sāyana system than on that of the nirayaṇa system.

*Both of them live in Bombay at present. See page 323.

MAN *EN RAPPORT* WITH PLANETS

Many people are sceptical as regards the connection between the planets in the sky and the affairs of human life, and their scepticism is quite natural. But the author believes that such connection exists. It is not possible at present to explain with precision why it should be so but the fact remains true all the same. The following account of astrologer Patvardhan, who used to guess the birth ascendant correctly by simply observing the physical traits of people may make his point clear to the readers.

BABAJI KASHINATH PATVARDHAN

He is better known as Mahadkar. He was born on the 14th lunar day of the dark half of Vaiśākha in Śaka 1787, when the ascending sign was Sagittarius, at Pacheri Sada alias MOBHAR, near Chiplun. The extraordinary knowledge of astrology which he possesses is mostly self-acquired. His father died when he was in his 13th year. He received his early Marathi education, first at Ganapati Pule in 1877 A.D. then at Malgund from 1878 to 1880 and then up to 1882 at the Marathi School No. 1 at THANA. Later on, in 1883, he was employed in the Court in Alibag district. He continued in Alibag court up to 1886 and then joined the court at Mahad ; hence, he became known as Mahadkar. Since 1893, he has left service and is carrying on legal practice at Ichalkaranji and mainly at Kolhapur. Most of his time is spent in other activities. In 1882, he met a Dravidian astrologer who was rather eccentric. He told Patvardhan certain basic principles of finding the birth ascendant by observing the physical traits of people. Later on, he developed this knowledge by reading serveral books himself reconciling as far as possible the different hints about physical traits gathered from different books and framing rules by observing hundreds of people. He became famous for the knowledge since 1891. He displays a very keen intelligence in casting horoscopes simply from the physiognamy of people ; for a moment he sees a person and he can cast his horoscope. He does so mainly by looking at the facial signs and sometimes by observing the tongue and the palm. He not only tells what the ascendant was and how the planets were placed at the time of birth by observing the physical traits but can also mention the degree of the sign occupied by every point. It has been the author's experience that there used to be at the most an error of only a degree or two. It is not that he always told the degrees of planets. He generally gave out only the signs. Any *Jośi* who knows mathematical astronomy can tell the date and time of birth if the native and his horoscope are before him. Jupiter returns to the same sign after 12 years and Saturn after 30. The Sun comes to Aries in every Caitra and so on. The tithi can be found from the distance between the sun and the moon. It is, therefore, evident that these conditions can help in finding the time of birth. If the birth-time of a person is given, the ascending sign at that moment and the positions of planets can be found with the help of astronomy. But Patvardhan can find the ascendant and planetary positions from the physical traits ; in other words, he can correctly say what sign was ascending at birth and how the planets were located in the houses. When these are inserted in the horoscope, the time of birth can be found by following the method described above.

This leads to the conclusion that the planetary positions in the sky and the sign ascending at the moment of birth give rise to certain physical traits. This goes to prove that man is *en rapport* with planets.

Many objections can, of course, be raised against this belief. It is needless to consider them at this place : and the matter cannot be considered fully till one can master the knowledge which Patvardhan has acquired. It has however, been stated that the conclusion which could be drawn has been put after consideration of the likely objections as far as possible.

Patvardhan tells people simply the time of birth and gives a brief reading, but nobody is able to say how he is able to do this. Hence they are unable to appreciate the importance of his art. Some people even think that the time of birth can be found by means of *siddhi* or psychic power developed through *mantras*. But this is wrong. The method of finding the ascendant at birth by observing simply the physical traits may be called *sãmudrik* (Palmistry). But the *sãmudrik* of Patvardhan has a close connection with astrology. It is the author's experience that many of the events, past and future, told by Patvardhan are found to be correct. But this branch of knowledge has not yet been completely mastered by him. Rules must be framed after verifying hundreds of cases. Patvardhan is mainly interested in finding ascendant at birth by observing physical traits. But even then, an instance may be cited where the ascendant could not be definitely given, where it remained doubtful : but such instances are few and far between. Again at times, the time of birth goes wrong by a year, a month, or a day ; and this is due to a very trivial cause. Jupiter stays in a sign for one year ; but it is not necessarily the case that it enters a new sign just in Caitra ; it may be found to occupy the same sign during two Śaka years. For example, Jupiter will occupy the sign Leo both during Śaka 1818 and 1819. The sun remains in the sign Meṣa both in Caitra and Vaiśākha. The same is the case with other months. The moon occupies a sign for about 2½ days. Hence, if an attempt is made to find the time of birth simply from the planetary positions in signs, the above error is sometimes likely to occur. Patvardhan knows how to find the planetary positions in terms of degrees in a sign. If these degrees are referred to the almanac there would be no room for error. If he attempts to tell the time of birth after carefully consulting the almanac, it is sure that his answer would be found to be correct in the case of at least 8 out of 10 horoscopes.

MUTUAL RELATION BETWEEN MAN AND MAN

The author came across instances in which Patvardhan correctly casts the horoscope of the son by observing the features of his father. He cites one such case. He cast within 15 to 20 minutes the horoscope, along with the positions of almost all the planets of Ganesh, the son of R.B. Narayanbhai Dandekar, after observing the latter's face. This feat has not been mentioned in any book. Patvardhan has himself hit upon the method by intuition. Anyway, it cannot be foreseen to-day what miracles would be possible through astrology. This science must be developed after testing cases by experience and then astrology like several other modern sciences would, it is believed, prove to be an excellent empirical science.

SCIENCE OF ASTROLOGY

There resides in *Kumbhakonam* a Śūdra named Govind Chetty. His art is even more amazing than that of Patvardhan. It is reported that he not only tells the correct time of birth but also the questions in any one's mind in

any language together with their answers. But it could not be known if he does this with the help of astrology. He is not known to have written a work on this subject, nor has Patvardhan written any book so far. If they do, that would be a lasting benefit to the world. Otherwise, their gifts would only pass into the realm of anecdote where we hear so much about *Jośīs* who once displayed marvellous powers of prediction, but whose trace was completely lost in course of time. Works on astrology do mention some methods of finding the birth ascendant from one's physical traits. But if there are some books on the art of Patvardhan and Govind Chetty, they are not accessible to all. There is however no doubt that the basic principles of this art are traditional.

Blessed are they who first determined the fundamental principles of astrology. They, for instance, discovered rules like the following : That certain peculiarities attend certain ascendants ; that the bodily condition of the native is to be judged from the first house ; that of the wife from the seventh ; that of wealth is considered from a particular house ; that a particular line on the palm denotes that the sun occupied a particular sign at birth and so on. We can safely say for the present that the science of astrology is built on some good foundation and that man is *en rapport* with planets.* It is difficult to describe briefly the true nature of astrological works. It is, therefore, proposed to relate the history of this branch in brief.

HISTORY

We know that the 'divine' works on astrology extant at present are Gaurī-Jātaka and Kālacakrajātaka or Kālajātaka, and the '*non-human*' or 'ārṣa' works (i.e. those compiled by SAGES), are *Pārāśarī, Jaiminī Sūtra and Bhṛgu Saṃhitā*. The Pārāśarī has two editions-Bṛhat and Laghu. The most ancient of the existing 'man-made' works on astrology is the Bṛhajjātaka of VARĀHA-MIHIRA. At the end of the work, Varāha remarks.

मुनिमतान्यवलोक्य सम्यक् होरां वराहमिहिरो रुचिरां चकार ॥

उपसंहाराध्याय.

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*Ever since Śaka 1815, the author has devoted considerable thought and effort in the light of Patvardhan's art to decide the question whether the sāyana or nirayaṇa system is true to nature so far as astrology is concerned. But no decision seems to be possible for the present. The positions of some planets, discerned by Patvardhan from physical traits are relative. For instance, he comes to know after reading the face, that there is a difference of 2° between the sun and Mercury or that a particular planet occupied a particular place from the ascendant. This does not lead to any decision. A still more important point is that the indications now established by Patvardhan were first based on Keropant's Patvardhanī Pañcānga. For example, he observed in a number of cases that a particular feature was connected according to Patvardhani Pañcānga with a certain degree on the ascendant or a certain degree denoted by a particular planet and then made it a rule to link that degree with the ascendant or planet in appropriate cases. He could as well have established such rules on the basis of the sāyana almanac from the very beginning. If people well-versed in Patvardhan's lore and able to understand the difference between sāyana and nirayaṇa systems would continually toil for keeping a record for five or six centuries, the difference in the sāyana and nirayaṇa positions of planets show an excess of 18° over the (nirayaṇa) positions which Patvardhan sets down from the physiognamy of the native. If after 600 years it is noticed that, maintaining Patvardhan's rules, the difference between the positions of planets as found from physical features and the sāyāṇa positions comes to 18° degrees only, the natural system for astrological purposes would prove to be a sāyana, and if it comes to 26°, then it would prove to be purely sidereal (i.e. nirāyaṇa). While reading horoscopes, Patvadhan adopts the nirayaṇa signs of exaltations and ownership, as also the nirayaṇa signs occupied by the planets and the ascendant. Nothing, however, can be decided from this.

meaning, "Varāhamihira after studying the views of sages, compiled this beautiful work on astrology." Chapter, headed 'conclusion.' Elsewhere, Chap 6, Verse 10, he also uses the word "Munigaditam" meaning 'mentioned by SAGES'. He has referred to PARĀSARA twice. He has referred to MAṆḌAVYA in the chapter on 'Graha-Gocara' in Bṛhat Saṃhitā. Similarly, Bhaṭotpala, the commentator on Bṛhatjjātaka has given quotations about astrology from the Gārgi, Bādarāyaṇa, Yājñyavalkya and Māṇḍavya works.

They include quite a large number of quotations from the Gārgī. Their works must have existed before Varāha. It shows *that there were at least five works compiled by SAGES before Varāhamihira. In addition to these names, Varāha has referred to *Ācāryas* like SATYA, MAYA, YAVANA, MAṆITHYA, JĪVAŚARMĀ, VIṢNUGUPTA**. Out of these, Satya's name occurs six times. There are, in addition, several vague references like "according to one, some one, others, earlier śāstras, the earlier writers, etc." From this it appears that a number of " human authors " had lived before Varāhamihira. He has definitely mentioned the names of *Six Ācāryas*, that 10 to 12 works were compiled, that they became popular and that five of them came to be adored as 'compilations of SAGES'—These things could not have possibly happened during a period of 50 or 100 years. They would easily require five or six centuries for this ; and Utpala remarks (commentary on 7.7 of Bṛhajjātaka) that the Viṣṇugupta, referred to by Varāha, was CĀṆAKYA himself. From this, he was possibly Cāṇakya Viṣṇugupta, the minister of CANDRAGUPTA ; and there are *no reasons to disbelieve this surmise.*

BEGINNING OF THE PRESENT SYSTEM OF ASTROLOGY

It, therefore, shows that works on astrology existed about 800 years before the time of Varāhamihira, which means that our people had developed the knowledge of astrology 4 or 5 centuries before the Śakas. Even though it might not have existed in the same condition in the beginning as at the time of Varāha, it must have gradually developed into that state. The present system of astrology may have come into vogue from the time when Meṣa and other names of rāśis were introduced about 500 years before Śaka era. It was, of course, preceded by the astrological system of the Atharva Veda.

If the knowledge of astrology dates as far back as 5 centuries before Śaka era, the system of mathematical branch of astronomy must have been equally ancient, because, no astrological consideraion is possible, unless the positions of planets in signs are known and the earlier discussion has shown that there is no reason for presuming that the branch of astronomy had not reached such maturity in such a remote period of antiquity. Moreover, it must be remembered that even though the mathematical branch had not been completely mastered, in other words even though the knowledge of true places and motions of planets was not attained, the ancients at least knew the mean motions and positions of planets and had undoubtedly attained before 500 B.S. a general

*Additional quotations from other sages such as Garga, Vaśiṣṭha, Bharadwāj, Śauṇaka and Atri are found in other books. There is reported to be another work entitled Varuṇa Saṃhitā.

**In addition to this, the names of Devasvāmī & Siddhasena occur in the verses 7 & 8, of Chapter 7, but Utpala says that the two verses do not belong to Varāha ; other additional names are those of Śakti and Bhadatta or Bhadanta. Utpala says that 'Śakti' here means 'Parāśra' and Bhadanta means 'Satya.'

knowledge of the sign positions of planets (p. 127 and 146 of pt. I). Even if the true positions and motions of planets cannot be correctly found by calculation, the naked eye can at least show where the planet is in the sky, when it becomes direct or retrograde, when it rose or set heliacally. So then the knowledge of mathematics need not necessarily have reached maturity when the present system of astrology came into vogue in this country. The reason why planetary motions were considered in our country and the science of astronomy reached perfection (of course, within the limits of our ancient works) and remained alive till today lies mainly in the necessity to judge the possible effects of the movements of planets. The works on Saṃhitā describe the effects of planetary movements. The desire to foresee these effects, the need of auspicious moments for sacrifices or other rites and the effects of planetary movements on each person as in natal astrology are the three reasons why the science of astronomy originated in this country, developed to a considerable extent and continued to exist. (In *Europe*, the main cause of its reaching a very high degree of development as at present was navigation. Still even there these very three things were mainly instrumental in the past in bringing the science to the same stage of development as in *India*). It is, therefore, evident that the present system of astrology must have been established before the science of astronomy attained 'its' full status ; that is, before the correct knowledge of finding true positions and motions of planets could be attained. Hence one cannot lightly dismiss as improbable the view that the present system of astrology became established in our country four or five centuries before Śaka era.

HISTORY OF WORKS ON ASTROLOGY

The question whether we have borrowed astrology from the Westerners will be considered in the concluding chapter. *Hundreds of works have been written on astrology*. It is difficult to read all of them. The author describes breifly the history of some of those few works of which he has got information either directly or through tradition and for whose dates he could find some clue. But all these works are merely A DROP IN THE OCEAN.

PĀRĀŚARĪ

Pārāśarī is a work much talked of by astrologers. It has two versions Bṛhat & Laghu. Laghu Pārāśarī is available and in extensive use. There are several commentaries on it. A work entitled Bṛhat Pārāśarī was printed in Śaka 1814 by Śrīdhar Śivalāl in the Jñānasāgar Press at Bombay. It consists of two volumes. Part One contains 80 chapters, but only 51 of them could be procured with difficulty from different places, and it is stated in the book that even these were fragmentary and had to be completed from other versions before they were printed by Śrīdhar, the son of Jatāśaṇkar. The first part contains 4196 verses. We have no means to ascertain which of them were original and which were interpolated by Śrīdhar or by the printers. At one place, a verse describing the method of finding the ayanāṃśa has been taken from the Graha Lāghava without acknowledging the source. In short, there is no sense in saying that part one, as it stands in a printed form to-day, is the same as the original work of Parāśara. Part two has 20 chapters. Most of the verses in it numbering 812 in all are in 'anuṣṭupa' metre. It has been remarked that whatever is not available in this part should be found from the Horāśāstra by Garga. At some places we are asked to adopt certain pro-

cesses after converting a planet's place into its Sāyaṇa equivalent. It shows that there must have been some admixture in it after Śaka 500. Part one of Pārāśarī which is in the Government Library at Tanjore contains 1650 verses. The first chapter in it is entitled "Rāśi Svarūpa". Its first two verses are as follows :—

मनोहरदाय दृष्टि (?) मंदहासलसन्मुखः । मंगलाय......सर्वमंगलाजानिरस्तु नः ।। १ ।।
मेषोक्षनरयुक्कर्किसिंहकन्यातुलादयः । धनुर्नक्रघटी......इति द्वादश राशयः ।। २ ।।

The editions printed in Bombay do not contain this chapter or these verses. The third chapter in it is headed, Rāśi Svarūpa, but that too does not contain these verses. The last chapter of the Tanjore version is entitled "Ariṣṭādhyāya", but it is the fifth chapter in the Bombay edition. It cannot be said with certainty if the Pārāśarī written before the time of Varāha is existent anywhere at present in its original form. Bhaṭotpala observes :—

पाराशरीया संहिता केवलमस्माभिर्दृष्टा न जातकं । श्रूयते स्कंधत्रयं पराशरस्येति ।
तदर्थं वराहमिहिरः शक्तिपूर्वैरित्याह ।।

वृहज्जातक, अध्याय ७ श्लो, १ टीका ।

"We hear that Pārāśarī has three parts. That is why Varāha has referred to Śakti (Parāśara) (See verse 1, Chap. 7.) But we have seen Parāśara's Saṃhitā only and not his Jātaka".

Pārāśarī was not well known even at the time of Bhaṭotpala (Śaka 888) ; how could it be so in the present time ? Laghu Pārāśarī which is at present available, is in the same condition. It is also known as Uḍudāyapradīpa. The author declares at the outset, "I am compiling this Uḍudāyapradīpa on the basis of Pārāśarī-Horā for the satisfaction of astrologers". It is clear from this that the work was not written before Varāha.

JAIMINĪSŪTRA

A very small work named Jaiminī Sūtra, with four chapters, consisting of aphorisms in prose form is now widely known. Several commentaries on it are available. This work contains Greek words like *riphpha*, *aār* etc. Varāhamihira and Bhaṭotpala do not make any mention of the Jaimimī Sūtra in their works. One may say, therefore, that if there was actually an *ārṣa* work entitled Jaiminī Sūtra, it is doubtful if it has been retained in its original form. Burnell says that Jaiminī Sūtra is in extensive use in MALABAR.

BHṚGU SAṂHITĀ

This is a very famous work. It appears to be an "ārṣa" work from its name, but Varāhamihira and Bhaṭotpala have not referred to it. It cannot be said, therefore,, with any certainty that the work belongs to a date earlier than the two authors. It is reported that the birth horoscope of any person can be found in it. If it be a fact, it must be a collection of 74649600 horoscopes, representing all signs on the ascendant and all possible positions of planets in the twelve houses. Assuming that 10 verses have been devoted to the reading of each horoscope, it must contain at least 75 crores of verses. Some horoscopes purporting to be extracted from Bhṛgu Saṃhitā are available,

from which it appears that there are different horoscopes for different degrees of each ascending sign. If such delineations have been given, the number of horoscopes would far exceed the above number. The author came across a printed copy of a part of Bhṛgu Saṃhitā in the possession of a Marwari gentleman of *Poona.* It contained about 200 horoscopes, with nearly 70 verses assigned to each horoscope and the total number of verses is 14000. The work abounds in solecisms of all sorts and the ascending signs in it are not arranged in any order. In the Government Library at *Jammu, in Kashmir,* there is a work named Bhṛgu Saṃhitā. The Library has a printed Catalogue of books which shows that the ascending signs in the work are arranged in order, and the total number of verses appears to be about 160000. If 70 verses are allotted to each horoscope as above, the work must be containing about 2300 horoscopes. Those who possess some parts of Bhṛgu Saṃhitā may, on certain occasion, be playing a hoax on the consultant by palming off on him a new horoscope in the name of Bhṛgu Saṃhitā. Nevertheless, there is no doubt that there does exist a work known as Bhṛgu Saṃhitā. The author has seen some horoscopes delineated from it and he is of opinion that such delineations are in a large measure correct.

There is a work in the Ānandāśrama of Poona, entitled " Bhṛgūkta Jātaka-Kalpalatā " compiled on the model of Bhṛgu Saṃhitā. It contains 1800 verses. It has considered about 200 combinations of planets staying in different houses ; in other words, so many horoscopes have been examined.

NĀḌI GRANTHAS

CHIDAMBARAM IYER B.A., referred to on page 287 before, writes in THE HINDU ZODIAC :—The works named Nāḍigranthas contain horoscopes for *all persons past, present and future.* The author has himself seen five Nāḍiworks and has heard of five more. The Dhruva Nāḍi by Satyacārya is the best of all. Seventy parts of it are in the possession of different persons in South India. It contains true nirayaṇa positions of planets at the time of the birth of each man. The difference between them and the accurate sāyana positions in the beginning of 1883 A.D. as found from the Nautical Almanac is found to vary from 20° 23′ 8″ to 20° 25′ 22″. From this 20° 24′ 15″ has been determined as the ayanāṃśa for that year. This statement contains two important facts. The first is that there are very voluminous works like the Bhṛgu Saṃhitā extant in the MADRAS Presidency ; and the second is that the planetary positions in them are correct within $2\frac{1}{4}$ minutes of arc, as compared with those of the Nautical Almanac. (The difference due to Ayanāṃśa is not an error). Chidambaram appears to be a learned and reliable gentleman from his writings. Hence, it is really very surprising that the planetary positions given in the Nāḍi works are so very accurate.

YAVANĀCĀRYA

Varāhamihira has referred to Yavanācārya. Bhaṭotpala writes in his commentary on verse 9, Chap. 7, of Bṛhajjātaka, "SPHUJIDHVAJA", the Yavana king compiled another scientific work after the beginning of the Śaka era ", Varāhamihira has cited the views of Yavanācāryas before him. The author has not seen Yavanācārya's work, but he has seen one by Sphujidhvaja. He has, in his work, remarked " The Yavanas i.e. the Greeks say ". This shows that one or more Greek astrologers, whose works were not available at the time of

Bhaṭotpala, lived before the time of Varāha. It seems to be Utpala's view that they lived before the Śaka era. There may have been only one Greek work, but it may be that it was followed by a number of Yavanas, (Greeks) and hence, the word 'Yavana' continued to be used in the plural. Bhaṭotpala has called Sphujidhvaja himself Yavaneśvara, and has taken quotations only from his works as if they belonged to Yavanas. (This work too is written in Sanskrit). There is a work, named Mīnarāja Jātaka, at present available. It is also known as Vṛddha Yavana Jātaka or Yavana Jātaka. It is remarked in the beginning of the work, "The science of astrology which was explained by a former sage to Maya had *one lakh* verses in it, but was abridged by Mīnarāja into 8000 verses". Bhaṭotpala has quoted 12 verses describing the nature of signs as extracts from Yavaneśvara (see commentary on verse 5, chap. 1, Bṛhajjātaka) and these are found in the Mīnarāja Jātaka. But many other verses cited by Utpala as extracts from Yavaneśvara are not found in the Mīnarāja Jātaka. From this it appears that the works by Sphuijdhavja and the Mīnarāja Jātaka are different from each other and the Yavana, who lived before Varāha, appears to be quite a third party. The later works were compiled by abridging or enlarging the ancient works, and the three writers possibly held the same view.

The works *Bṛhajjātaka and Laghujātaka* by VARĀHAMIHIRA and PṚTHUYAŚĀ'S work, *Ṣaṭpañcāśikā,*' are now-a-days in use. All these three works have commentaries of Utpala. Ananta, brother of Ganeśa Daivajña, author of the *Grahalāghava*, wrote a commentary on Laghujātaka in Śaka 1456. There was a commentary on Bṛhajjātaka by *Balabhadra,* in addition to those by *Mahīdās* and *Mahīdhar*. The two latter and Mahīdās and Mahīdhar, the commentators on Līlāvatī, might have been the same persons. There is another commentary named Subodhinī on Bṛhajjātaka in the Govt. Library at Tanjore. The Aufrecht Catalogue mentions 5 or 6 more names of commentaries. The Mīnarāja-Jātaka contains quotation from LALLA. NṚHARI, the author of Jātakasāra, has also mentioned Lalla's name among the authors of astrological works. This shows that Lalla may have written a work also on astrology. Bhaṭotpala has borrowed a number of quotations from *Sārāvalī,* and one of these quotations has mentioned Varāha's* name. From this Sārāvalī appears to be a work, compiled after Varāha but before Śaka 888. A work named Sārāvalī has come to my notice. (The quotations given by Utpala could not be found in it.) Its author is one Kalyāna Varmā. He has also called himself as Vaṭeśvara. He has compiled the work after selecting different portions from the works by Varāhamihira, Yavana Narendra and others. An astrologer named Vaṭeśvara lived about Śaka 821. (See page 190). It would appear, therefore, that the Sārāvalī quoted by Utpala and the one compiled by Kalyāṇa Varmā are the same work, and its date is about Śaka 821**. The commentary by Utpala mentions the names of Devakīrti (1.19) and Śrutakīrti (1,7,8,9) in addition to the above. There is a work, Jātaka Paddhati, on astrology by Śrīpati. I think that this Śrīpati and Śrīpati, the writer of Ratnamālā, are one and the same person, considering the commentaries of Mādhava on these two books. Mādhava's commentary on Ratnamālā mentions *Vṛddha Jātaka,* a work on astrology, which shows that the work belongs to some date prior to Śaka 1185. Keśava of Nandigram (about Śaka

*See commentary on Chap. 7, Verse 13.

**Sudhākara says that it mentions the names Mandil, Devakīrti, and Kanakācharya. According to Sudhākara the date of its compilation is the same as that of Brahma Gupta, but the view has not been supported by any proofs.

1418) has, in his commentary on Jātaka Paddhati, cited the following works and authors :—Śrīdhara Paddhati, Mhalugī Paddhati, Dāmodhara, Rāmakṛṣṇa Paddhati, Keśava Miśra, Vallayu Paddhati, Horā Mārkaṇḍa, and, Laghu Paddhati. The first four of these names occur even in the Viśvanāthī commentary. All of them must have lived before Śaka 1418. Bhāskarācārya has mentioned one Śrīdhara as the author of a work on Bījagaṇita (Algebra). Mādhava, the commentator of Ratnamālā, has referred to one Śrīdhara, with reference to a Muhūrta work. All the three Srīdharas and the Śrīdhara, author of Gaṇitasāra mentioned before on page (95), may have been the same person. Dāmodhara himself may be the compiler of Bhaṭatulya Karaṇa (Śaka 1339). There is a small book on astrology, named, Bhāva Nirṇaya, written by Vidyāraṇya. A small work consisting of 40 verses, entitled Jātakapaddhati, compiled by Keśava of Nandigram is very widely known. The work itself is called Keśavī. Keśava has himself written a commentary on it. Viśvanātha has written an 'Udāharaṇa' commentary (Page 156). Nārāyaṇa (Page 158) and Divākara (Page 162) have also written commentaries on the work, and the Aufrecht Catalogue mentions 7 more. It is at present printed with its Marathi translation and 'Udāharaṇa' in Marathi. There is an astrological work entitled Jātakabharaṇa by Dhuṇḍiraj. It belongs to about Śaka 1460 (see Page 146). It states astrological effects in a definite order and hence it is very useful in casting horoscopes. There is one Jātaka Paddhati of Śaka 1480 (circa) by Ananta. The work Jātakottama is referred to in the commentary on Muhūrta Mārtaṇḍa which indicates that the work belongs to a period before Śaka 1493. A work named Jātaka Muktāvalī by Śivadāsa has been mentioned in Viśvanāth's Commentary on the Jātaka paddhati of Keśava. There is a voluminous work, entitled Horāskandha-Nirūpaṇa, which was compiled by Viśvanāth Pandit, son of Rāma, under the direction of King Vīrasiṃha. It is also entitled 'Vīrasiṃhodaya Jātaka Khaṇḍa ". The date of this work could not be found ; but, as it combines quotations from the *Jātakābharana*, it must have been compiled after Śaka 1460, probably about Śaka 1500. It is very useful to those who prepare horoscopes, since it describes *results of planetary positions in an orderly manner* after quoting lines from several ancient works. It was not seen in a printed form anywhere, but it is really worth printing. It contains quotations from several ancient works. Among them are found names of authors like Śaunaka and Guṇākara and those of works like Samudrajātaka, Horāpradīpa, Janma Pradīpa. There is a voluminous work named Jātaka Sāra by Nṛhari. The author remarks in it in the beginning, " *Vaśiṣṭha, Garga, Atri, Parāśara, Varāha, Lalla* and others have compiled Scientific works on Horā. But the results in them have not been given in an orderly manner. In order, therefore, to enable one to write the effects (of planets) in the horoscope in a systematic way, I am writing this work with the help of Sārāvalī, Horāpradīpa, Janma Pradīpa and similar other works." There is a work, Jātakālaṅkāra, by Gaṇeśa which is in extensive use. *Kānhajī*, the grand father of Gaṇeśa and a Brāhmaṇa of Bharadvāja gotra, was highly esteemed at the court of a king of Gujerat. He had three sons, *Sūryadās, Gopāla* and *Rāmakṛṣṇa*. Gopal's son Gaṇeśa compiled the Jātakālaṅkār at Bradhnāpur in Śaka 1535. It has six chapters. Gaṇeśa's guru was named *Śivadāsa*. The author hapned to learn from a book that *Bradhnapur* is the same as Burhanpur. But it cannot be said for certain that *Jātakālaṅkāra*, was written at Burhanpur. This work, has a commentary by *Harabhānu*, son of *Kṛṣṇa* and surnamed Śukla. The commentaror says that Bradhnapur is the same as Sūryapur. Divakar, referred to on page 162, has to his credit a work entitled 'Padmajātaka',

consisting of 104 verses, which was compiled in Śaka 1547. A work named *Paddhatibhūṣaṇa* was compiled in Śaka 1559 by Soma Daivajña, son of Rudrabhata who was a Rgvedī Brāhamaṇa of Jaladagram. This Jaladagram may be the same as Jalgaon, in Khandesh. The work *Paddhati-bhūṣaṇa* has a commentary by Dinkar, in which Śaka 1729 has been adopted for the example. It is not known if this Dinkar is the same as the one described on page 175. Balabhadra, son of Damodar, wrote a work named *Horā Ratna*. It may have been wirtten about Śaka 1577. *Horā Kaustubha* is a a work compiled by Govinda, son of Narahari, about Śaka 1600. The two works, *Horā Sāra Sudhā Nidhi* and *Nara Jātaka Vyākhyā*, by Nārāyaṇa belong to Śaka 1660 (circa). Sudhākara writes that there is a good work on Astrology, entitled *Praśna* Māṇikyamālā, by Paramānanda Pāthak. It consists of four parts. Paramānanda, who was a Sārasvata Brāhmaṇa, was the chief astronomer at the court of Balvant Singh, king of Varanasi, about Śaka 1670. There is a work *Paddhati Candrikā* by Rāghava (see page 175). According to Sudhākara, there was a capable Jyotiṣī named Govindāchārī at Varanasi. He was skilled in '*māraṇa*' (killing by magic) '*Mohana*' (hypnotism) and such other occult practices ; he later on settled near goddess Vindhyavāsinī and compiled two or three works including *Sādhanasubodha*, *Yoginī-daśā* etc. after Śaka 1775. He died in Śaka 1782. Anantāchārya Mhalagī a resident of Sholapur, and an astrologer, has written works entitled *Anantaphala-darpaṇa* and *Āpābhatī Jātaka*. The first was written in Śaka 1798 ; it deals with both *Jātaka* and *Tājaka*. One Āpā Jośī Bhāṇḍārkavathekar was the preceptor of Anantāchārya. (He died about Śaka 1788). All his predictions used to prove very accurate. He had formulated some new rules after making some modifications in those ancient works. Anantāchārya said in Śaka 1806 that these revised rules are to be found in his own works.

KERALA SYSTEM

There is a system of astrology known as the *Kerala system*. It appears to propound certain rules which differ from the rules usually found in other works. There are several works on the Kerala system.

HORĀ ASTROLOGY

Whether an event will happen at all, and if so, when and how—such and other questions are put to astrologers. There are several systems of dealing with questions (praśna). One of the systems is to answer a question from the ascending sign in the horoscope which is cast for the moment when the question is put and hence the 'praśna' forms a part of the 'Horā-Branch' or astrology. But some of the methods of examining a question have nothing to do with the science of astrology. But there is a popular belief that one who is known as a Jyotiṣī must be able to give out predictions about each and every matter ; and hence any question can become a subject for astrologers' scrutiny and each book on 'Praśna' is included in astrological Literature. There are several works on 'Praśna' or Horā astrology. Praśna Nāradī is a small manual attributed to a sage, which contains only 32 verses. It is said to be a part of the *Nārada Saṃhitā*. But the Nārada Saṃhitā, as it is at present, resembles the Bṛhat Saṃhitā and does not contain this Chapter. Among the 'human' (Pauruṣa) works extant at present, the work Praśna Jñyāna or Praśna Samāpti' by Bhaṭotpala consisting of 70 couplets, appears to be the most ancient (Śaka 888).

RAMAL

There is a system of Praśna Vidyā (question horā) in which all the faces of dice are marked with dots and problems are answered according to the casting of the dice. This system is known as '*Pāśak Vidyā* or *Ramal*'. Ramal is an Arabic word. In the sanskrit works on the subject of 'Ramal' which are extant at present, one comes across technical terms which are mostly Arabic ; and hence one is likely to think at first-sight that this system originally belonged to Muslims but that is not so. A manuscript written on birch tree leaves in a script current in the times of ancient Gupta kings has been found by a European gentleman named BAUER. They consist of treatises devoted to three different subjects. It has been proved that the book was written some time between 350 to 500 A.D. In that work* is found a system somewhat similar to the present Ramal system ; but most of the terms used in it are sanskrit and some Prakrit. There is a copy of the Garga-Saṃhitā in the Royal Library at Tanjore ; which contains a chapter captioned "*Pāśakāvalī*" consisting of 235 verses. A verse from it has come to author's notice ; it contains** the technical term 'Dundubhi' which occurs also in the work referred to above: This proves that the Rāmal Vidyā originally belonged to this country. The language of the 'Pāśakāvalī' included in *Bauer's* manuscript, suggests that it may have belonged to the 3rd or 4th century*** before Śaka era and it appears from this, that the 'Pāśak-Vidyā' was known in this country in those days. As time elapsed, the original sanskrit works disappeared and fresh works were written in sanskrit on the basis of Arabic works. It cannot be said for certain from what date they began to be so compiled. Bhaṭotpala and Śrīpati have each a work on Ramal to their credit according to Aufrecht Catalogue. The work Ramalāmṛta written in Śaka 1667, refers to Ramal-works by Śrīpati and Bhoja. One wonders whether Jyotiṣīs from Sind who had gone to Arabia in the 7th Century of the Śaka era, might have brought back Ramal works with them. The author does not know if the systems embodied in the two, Pāśakāvali works mentioned above and in Ramal are identical. Such a comparison alone can decide if the art of Ramal was independently developed by the Muslims or whether transmitted from India in ancient times.

There are several works on Ramal. An astrologer, Cintāmaṇi by name, wrote a book named *Ramal Cintāmaṇi.* It contains about 700 verses. The copy of the work in the Ānandāśrama was written in Śaka 1653. It may have been, therefore, compiled before Śaka 1600. Jayarāma, an Audīchya Brāhmaṇa and a resident of Prakāśe in Khandesh compiled Ramalāmṛta at Surat in Samvat 1802 (Śaka 1667) which contains about 800 verses.

DREAMS

Prophecy based on dreams and the falling down of lizards may be said to form part of either Saṃhitā or Horā ; works written independently on them are some times found.

*Articles containing an account of the discovery of the manuscript in some part of the text and an estimate of its date of compilation have appeared in the Journal of the Bengal Asiatic Society, for Nov. 1890 and April 1891, as well as in the issue of the *Indian Antiquary* of 1892 A.D. At present, the work is being printed by Dr. Rudolf Hornul.

**Burnell's Catalogue.

***Bauer's manuscripts contain a work on 'Mantra Śāstra' which clearly appears to have been written by a Buddhist. The Sanskrit of Pāśakāvalī is not quite pure. The followers of Buddhism were more inclined to compile works in Prakrit than in Sanskrit. It would appear from this that Pāśakāvalī may have belonged to the times of Candragupta.

TĀJIK

Tājik is the name of that system by which predictions are made about the happiness or woe to be experienced by any man during any year of life, by interpreting the ascendant and planetary positions in the horoscope cast for the beginning of that year when the Sun's longitude is exactly the same as at birth, which, in other words becomes a horoscope for the moment when a person completes one year of life by the solar reckoning and begins the next. There is a work on 'tājik' named Hāyaṇaratna' by Balabhadra,* son of Dāmodara. The following remark is found in it :—

यवनाचार्येण पारसीकभाषया प्रणीतं ज्यातिःशास्त्रैकदेशरूपं वार्षिकादिनानाविधफलादेशफलक-
शास्त्रं ताजिकशब्दवाच्यं तदनंतरभूतैः समर सिंहादिभिः ब्राह्मणैः तदेव शास्त्रं संस्कृतशब्दो-
पनिबद्धं ताजिकशब्दवाच्यं ।। अत एव तैस्ताएव इक्कवालादयो यावन्यः संज्ञा उपनिबद्धाः ।।

This also mainly gives the same definition as the one given above. It would also show that the Tājik branch was borrowed from the Yavanas. There is a work, named Tājik Bhūṣaṇa Paddhati by Gaṇeśa, son of Dhundiraj, a resident of Pārthapur, compiled about Śaka 1480. The writer remarks in it :—

गर्गाद्यैर्यवनैश्च रोमकमुखैः सत्यादिभिः कीर्तितं। शास्त्रं ताजिकसंज्ञकं ।।

(Meaning. The Science known as Tājik which has been propounded by Garga, Satya and other Greek writers like Romaka mukha........)

This also shows that it was borrowed from the Yavanas. There is a Tājik-work, named *Daivajñalaṅkrti* by *Teja Siṃha*. It appears** to have been written about 1300 A.D. as can be seen from the estimate of its date made by Prof. Bhandarkar. There is a work named Tājik Tantrasāra by SAMAR SIṂHA. There is a copy of it*** in the Deccan College collection written in Samvat 1491 (*i.e.* Saka 1356). From this it appears to have been completed many years before the date. The Samar Siṃha referred to by the author of 'Hāyana Ratna' may have been the same person. Anyway the Tājik-branch

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*Balabhadra was a Brāhamaṇa of Bharadvāja Gotra and a resident of Kanauj on the bank of the Ganges. His guru was one named Rāma. He states that he wrote the work when he was living at Rājmahal with Shahsuja, the 'lord of the Earth'. His grand father, Lāl, was a Jyotiṣi. His sons Devīdās, Kshemankar (Kshemakarna), Nārāyaṇa, and Chaturbhuj Mishra were all scholars. Devīdās has written a work on arithmetic and a commentary on the Śrīpatipaddhati. Dāmodara has written a commentary on Karaṇa Kutūhala by Bhāskara. Balabhadra had a younger brother, Hari by name. All this account is given in Hāyaṇa-Ratna. The date of the work is given in the following lines :—

योगो मासकृतेः समः करहृ (?) तो योगस्तिथिः स्यात्तिथिः
त्रिघ्ना वारमितिस्तदर्धं (? दूध्वं) सदृशं (दशं) भं सर्व योगो युतः ।
भूबाणाक्षकुभि १५५१ भंवेच्छकमितिर्ग्रन्थस्य ।।

There are some doubtful places in this. The author has no time at present to find the date by trying different years and months. Sudhākar has found Śaka 1564 as the date from the verse but it is wrong. This date of the work is stated to be 1656 A.D. in the Aufrecht Catalogue.

***Report on the Search for Sanskrit manuscripts* for the year 1882-83.

***The year 1491 noted against No. 322 of 1882-83, in the Deccan College collection seems to be a year of the Vikrama Samvat since calculation shows that the date of compilation, "Thursday, the 10th Lunar day of the dark half of Mārga Śirṣa" agrees with Thursday, the 10th Lunar day of the Amānta Mārga Śirṣa of Śaka 1356".

of astrology must have been introduced into our astrology after Śaka 1200, that is, after Muslim rule was established in our country. In many books the word 'tājik is found in its sanskritized form '*Tārtīyak*' ; but it seems to have been formed from the word 'Tājik' itself. The word 'tājik' is also written as tājak

When we say that we have borrowed the 'tājik' branch from the Yavanas, it simply means that we adopted from the Yavanas the idea of giving the annual reading from the ascendant of the annual horoscope which is cast for the moment of one's entry into a fresh year of life, and some technical terms about it. The rules of casting the horoscope and the rules for predicting results therefrom are almost the same in the Tājik as in the Jātaka and they originally belonged to us.

There are several other works on Tājik in addition to those mentioned above. There is a work, named Tājik-paddhati by Keśava of Nandigram, with commentaries by Māllari and Viśvanāth. There is also a work, Tājaksāra, written by Haribhatta about Śaka 1445. There is also another work named Tājakālaṅkāra by Sūrya, the son of Jñānarāja (*see* page 144). Tājik Nīlakaṇṭhī is a work written (by Nīlakaṇṭha) in Śaka 1509. Govinda, the son of Nīlakaṇṭha, wrote a commentary on it named Rasālā in Śaka 1544 : which has been printed. Similarly, Mādhava, the grandson of Nīlakaṇṭha wrote a commentary on it in Śaka 1555. (*See* pages 147-149). Viśvanātha also has written a commentary on it. This work is at present in extensive use. Bālakṛṣṇa of Yājñavalkya Gotra, a resident of Prakashe on the northern bank of the Tāpti, wrote a work entitled Tājik Kaustubha in Śaka 1571. The names of the ancestors of Bālakṛṣṇa, from his father upwards were Yādava, Rāmakṛṣṇa, Nārāyaṇa and Rāma. There is a voluminous work entitled Tājak Śudha Nidhi by Nārāyaṇa, written about Śaka 1660 (see page 168)

EPILOGUE

We have so far discussed Indian astronomy in elaborate detail. The condition of astronomy in the Vedic and Vedāṅga periods preceding the Siddhāntic period was described in Part I and that in the Siddhāntic period in Part II. Each of the three main branches of Jyotiṣa *viz.* Gaṇita*, Saṃhitā and Jātaka has been separately treated in Part II. Now the author offers his concluding remarks on this Survey.

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* The author will add here some more information about other mathematical works which were received later (From the *Notes on the Hindu Astronomy* by J. Burgess, 1893 :—).

(1) Europeans first obtained some knowledge worth the name about Indian Astronomy from a copy of an astronomical work procured from Siam. This work has adopted 365d-15i-31p-30v as the length of the year (which is the same as that in the original *Sūrya siddhānta* and *Khaṇdakhādyaka*). Cassini, a French astronomer, says that the epochal positions have been given for Saturday, the new moon day, 21st March, 638 A. D. (According to the original *Sūrya Siddhānta*, the mean Aries ingress occurred on the 2nd lunar day of the bright half of Vaiśākha, Ś*aka* 560, i.e. Sunday the 22nd March 638, at 12gh. 58p. after (mean) sunrise, and the preceding mean new moon of Caitra occurred on Friday at 49gh-35p i.e. on Saturday, 21st March according to European reckoning) The original epochal positions may have been true for Narasingpur near Pithāpur in Godāvari district or for Vārānasi. The sun's apogee given in this work is 80°- The maximum value of the equation of centr of the Sun is 2°-14′ and that for the Moon is 4°-56′. This shows that the work may have followed either the original *Sūrya Siddhānta* or some Karaṇa work now lost, by Āryabhata I who followed the *Sūryu Siddhānta*.

(2) *Ullamudayan's Karaṇa*, Śaka 1165.

WHAT FOREIGN ELEMENT HAS ENTERED INDIAN ASTRONOMY

Most of the European scholars are of opinion that the Indian people borrowed astronomy, particularly mathematical astronomy and astrology from the Chaldeans (Babylonians), the Egyptians or from the Greeks of *Alexandria.* This view has already been considered incidentally in the foregoing pages. The question will now be thrashed out in greater detail here and then other matters will be taken up for consideration in this conclusion.

NAKṢATRA SYSTEM NOT BABYLONIAN

The question, to whom the nakṣatra system originally belonged or who first originated the Rāśi system is immaterial. The author has already stressed the fact that what is really of supreme importance is the mathematics relating to the mean motions and true motions of planets. He has, however, come across an important article concerning nakṣatras which is summarized below :—

This important article on the question whether the nakṣatra system originated with the Babylonians was written by *Dr. Thibaut* in 1894 in the *Bengal Asiatic Society's Journal.* Vol. 63 for the year 1894. A number of *Babylonian* tablets have been recently excavated. Father *Epping* took great pains to decipher the writings on the clay tablets with the help of Father *Strassmaier* and published some facts of astronomical interest in his book, *Astronomisches and Babylon* in 1889 A. D. The tablets which have been found, contain many

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(3) The *Vākyakaraṇa*, Krishnāpur Śaka 1413. The new moon preceding the epoch of the work, i.e., the 30th lunar day of the previous year's Phalguna fell on 10th March. Warren attributes the work to Vararuci.

(4) The *Pañcāṅga Śiromaṇi*, Narsāpur, 1569 (or 1659). The length of the year adopted by these two works is 365d-15g-31p-15v, that is the same as that of the first *Ārya Siddhānta*. They, however, give 2°-10′-34″ as the equation of centre for the Sun and 5°-2′-26″ as that for the Moon.

(5) The *Graha Taraṅgiṇī*, *Śaka* (n) *1*618.

(6) The Siddhānta Mañjari 1619. From Warren's *Kālasaṅkalitā*:—

(7) Mallikārjuna's Karaṇa-work, Śaka 1100. The *abdaps* etc. adopted by it are true for the longitude of Rāmeśwara. Mallikārjuna was a Telang. From this it seems that this work may have followed the S. S..

(8) Bālāditya Kallū's *Karaṇa* work, Śaka 1378, true for the longitude of Rāmeśāara. (From the list of books presented by Bentley to Cambridge University).

(9) The *Brahma-Siddhānta*, 26 Chapters, 11 of which are devoted to astronomy and the remaining to *Muhūrta* etc. It begins with the verse :—
"Om shryarkaḥ paramo bramhā shryarkaḥ paramaḥ Shivaḥ."

(10) The *Viṣṇu Siddhānta* containing 11 chapters. The opening verse is the same as the one in the *Brahma Siddhānta* above.

(11) The *Siddhānta Laghukhamāṇik*, 15th Century A. D. compiled by Keśava, follows S. S. and contains 9 chapters.

(12) The *Sūrya Siddhānta Rahasya*, compiled by Rāghava, Śaka 1513.

(13) Mathurānātha's *Sūrya siddhānta mañjarī*, Śaka 1531. Mathurānātha was an astronomer at the court of a king named Śatrujit.

(14) The *Jyotissiddhānta Sāra*, Śaka 1704 ; this is compiled by Mathurānātha (referred to on page 174 before); contains 8 chapters. Sadānanda, father of Mathurānātha, was originally a resident of Pātnā, but later on shifted to Vārānasi. This work appears to have been written with the help of some European work.

(15) The *Graha Mañjari.* The date of its compilation has been given, but it is not quite intelligible.

records of observations. For example, "On the 20th night of the month of *Airu* (April or May) in the 189th year (124 or 123 B. C.) of the Seleucidan Era, Venus was visible or expected to be visible in the eastern part of the sky. The star in the region of the head of the constellation Aries appeared at a distance of 4 yards above it.* In the same year Mars appeared in the eastern sky on the 26th night of the month of *Abu* (July or August). At a distance of 8 inches above it was seen the Western star in the mouth of the constellation Gemini, in the same year, Mercury set while in the sign of Taurus, on the 4th day of the month of *Airu.* In the year 201 of the seleucidan Era, Mars rose in the sign Libra on the 8th night of the month of Tischritu". Considering all these things, Thibaut came to the conclusion that the Babylonians used to indicate planet's positions with respect to the signs and that the 27 or 28 divisions of the ecliptic called nakṣatras were never current among them. Thus there is no room left for the contention that the Hindus borrowed the nakṣatra system from the Babylonians. In other words the contention must be dismissed as worthless.**

VIEWS OF EUROPEANS

Let us now examine the views of Europeans regarding planetary motions and astrology. Some of our people regard the views of European scholars as gospel truth, no matter what the calibre of the scholar concerned is.

It is really surprising that even some of our seasoned scholars feel that way. But it is not proper to arrive at any conclusion unless we consider the *locus standi* of the scholar delivering the judgment on some question or unless we are ourselves fully entitled to form our own judgment. Other people naturally rely upon the views of eminent scholars, and hence, such scholars should declare their views only after due consideration. Now, as for making a pronouncement on the mathematical branch of astronomy in India and Europe, one is entitled to compare the works compiled in the two nations and to de-

* It could not be decided whether the information contained in these writings was the record of positions actually seen or of those which were expected to occur in future. The capacity to predict requires knowledge of mathematical astronomy. It has not been definitely known if the Babylonians possessed such knowledge in those times.

** While commenting on this point, Thibaut remarks that history does not support the view that the Chinese nakṣatras were originally 24 in number, and that later on about the year 1100, they became 28. Although Thibaut observes that all the three system viz. the Hindu, the Chinese, and the Arabic have much in common, he has not given any reasons for this similarity. But in his private letter dated 5th September 1896, he writes to the author ; "I have not as yet found a satisfactory explanation for the similarity of the Chinese, Arabic, and Hindu nakṣatras". If any two persons, who have absolutely no relation to each other, begin to select stars lying on the moon's path, they will naturally select prominent stars of the first magnitude, like Rohiṇī, Punarvasu, Maghā, Citrā and Jyeṣṭhā. The same would be the case with Aśvinī and other stars of the second magnitude. Similarly, clusters of faint stars like those of Kṛttikās will be found in the selecton of both. This principle is acceptable to Thibaut and should be equally acceptable to others. Still in view of the fact that the stars Mṛgaśirṣa, Mūla, Pūrvā and Uttarā Bhādrapadā, and Bharaṇī are common to all the three systems, that Pūrvā and Uttarā Phalgunī are selected by the Hindus and the Arabs, while the Āśleṣā nakṣatra is common to the Hindus and the Chinese. Thibaut is inclined to believe that the three systems must have originated from a common source. But if the moon and the stars are observed for about 10 years, or even for one year, the stars chosen by two or three persons will naturally be found to agree not only this, but also one cannot but be convinced that all the nakṣatras have been suggested to the Indian mind in the natural course. The author is convinced in that respect by observing the moon's conjunction with stars for more than ten years. It is not that the Chinese nakṣatra system tallies with that of the Hindus completely. There is some difference between the two; and it is quite probable that the Chinese might have established their system independently.

clare who borrowed from whom, if only one has a fair knowledge of the practical and theoretical astronomy of both India and Europe, or of one of these two pairs or at least of some part of practical or theoretical astronomy of both. Similarly, for making a pronouncement on astrology, one must have at least an elementary knowledge of astrology in addition to the competence mentioned above. In the same way, one must have sufficient means at one's command for one's competence in this respect varies with such means. Such means as would enable one to pass a correct judgment on Indian astronomy are multiplying every day. The means that we possess at present were not available 10 years ago.

Colebrooke, *E. Burgess*, *Whitney*, and *Dr. Thibaut* have expressed their views on the mathematical branch. The author has no first hand knowledge of Greek astronomy, but some facts could be gleaned from the writings of these four scholars. He is, therefore, reproducing here, verbatim, necessary passages from their writings. Even European scholars have no knowledge of Greek astronomy before the times of *Ptolemy*, because, as *Thibaut's* remarks would show later, it is not available at all. *Colebrooke* gave his verdict during the period from 1807 to 1817 A. D. The verdicts of the next two were given about 1860 A. D. while that of Thibaut was given in 1889. Much of the information about Indian astronomy that is given in this book was not available to *Colebrooke*. A considerable part of it was also not available even in the times of *Burgess* and *Whitney*. Most of it is now available to *Thibaut*, though part of it is still wanting. Apart from the question of the material at their disposal, all of them are competent to judge this question and their judgment, favourable or adverse, must naturally carry weight. *Burgess* and *Whitney* had the same material in hand (see page 43) and yet they have expressed divergent views. *Bentley* has not devoted much thought to the question regarding the origin of astronomy. *Dr. Kern* in his Preface to the *Bṛhat Saṃhita* (1865 A. D.) and *James Burgess* in an article published in 1893, have made only some passing remarks on the question. Both of them have expressed the view that the Hindus have borrowed both astronomy and astrology from the *Greeks*. But as they have not written articles specially on this subject, their discussion is not elaborate and is lacking in necessary evidence, and, therefore, the author is not reproducing it here, though he will incidentally deal with their views later. Apart from these authors, he has neither seen nor heard of any English article on this subject written by a competent European scholar. No one from amongst our own people too appears to have written on this subject. The views set forth below may also impart some new information regarding Indian astronomy. *Colebrooke's** essay contains his views both on mathematical astronomy and astrology, as also his views on the astronomy of the Arabs. It was once believed by some that the Hindus borrowed astronomy from the Arabs but owing to the additional information that has since become available, there is not even a shadow of doubt today that it was the Arabs who first borrowed astronomy from the Hindus. It has already been mentioned before that the Tājik system was transmitted to our country by the Muslims.

* Henry Thomas Colebrooke was born in 1765 A. D. He came to India in 1782. He became Chief Judge of the Civil Court, Calutta in 1801. He spent a lakh of rupees in buying Sanskrit manuscripts. These are now entrustod to the India Office. His articles were published in the *Asiatic Researches*, Vol. 9, 1807, in Vol. 12, 1816, and with the translation of *Pāṭigaṇita* and *Bīja Gaṇita* in 1817. All of them were collected and published in 1872 A. D. under the title *Miscellaneous Essays* by Colebrooke, Vol. II". The above extracts have been taken from this book. The pages mentioned refer to the book published in 1872.

COLEBROOKE

Colebrooke writes (1807 A D.) (p. 322) "I apprehend that it must have been the Arabs who adopted (with slight variations) a division* of the zodiac familiar to the Hindus." (p. 344) "The Hindus have likewise adopted the division of the ecliptic and zodiac into twelve signs, agreeing in figure and designation with those of the Greeks and differing merely in the fact that their initial point is carried on a few degrees further west than that of the Greeks. That the Hindus took the hint of this mode of dividing the ecliptic from the Greeks, is not perhaps altogether improbable ; but, if such be the origin of it they have not implicitly received the arrangement suggested to them, but have reconciled and adapted it to their own ancient distribution of the ecliptic into twenty-seven parts." "In like manner, they may have either received from the Greeks or given them the hint of an armillary sphere as an instrument for astronomical observation; but certainly they have not copied the instrument which was described by *Ptolemy*, for the construction differs considerably." "The *Almagest*** was first translated into Arabic in 827 A. D. by *Alhazen Ben Yusef.* Other versions are also mentioned but none of them are anterior to the ninth century." (p. 364) "The Hindus, like the Egyptians and Babylonians, divide each sign into three parts (which are called Dreṣkāṇas)." (p. 527)- "The Dreṣkāṇa system is not implicitly the same among the Hindu astrologers, which it was among the *Chaldeans*, with whom that of the Egyptians and Persians coincided. Variations have been noticed," (p. 371). "This astrological notion was confessedly received from foreign nations.." "The doctrine seems to be ascribed by *Firmicus* to *Nekepso*, king of Egypt : and Psellus cites a Babylonian author whom he calls *Teucer* and who is also noticed by *Porphyrius.* The word 'Dreṣkāṇa' is supposed to not be originally Sanskrit. For the same reason, it is likely, that the astrological doctrine itself may be exotic in India. The casting of nativities, though its practice is of more ancient date in India, may also have been received from *Western astrologers : Egyptians, Chaldeans* or even *Greeks****. If so, it is likely that the Hindus may have received astronomical hints at the same time. By their own acknowledgment, they have cultivated astronomy for the sake of astrology; and they may have done so with the aid of hints received from the same quarter from which their astrology is derived. The name of *Yavanācārya* would not be alone decisive. It will be requisite to collect all the passages in which *Yavanācārya* is cited by sanskrit authors and to compare the doctrines ascribed to him with those of the Grecian writers on astronomy". (1816 A. D.) (p. 399). " The planet revolves with an equal but contrary motion in an epicycle, of which the centre is carried with like but direct motion on a concentric orbit. To account for the still greater apparent irregularities of the five minor planets, the Hindu astronomers make them revolve with direct motion on an epicycle borne on an eccentric deferent. (In the case of the two inferior planets, the revolution in the eccentric is performed in the same time with the sun : consequently the planet's motion in its epicycle is in fact its proper revolution in its orbit. In the instance of

* These are the exact words of Colebrooke and it is clear from the context that they refer to the twenty-seven naksatra divisions of the zodiac. In the Marathi translation of this sentence, however, the phrase 'twelvefold division' (*dvādaśadhā vibhāgāci paddhati*) seems to have crept in through oversight. The same passage has been referred to elwsewhere when it is correcty interpreted in its bearing on the nakṣatra divisions.

(R. V. V.)

** The *Almagest* is the same work as *Mijasti* mentioned before.

*** Colebrooke reiterated the view in 1817, that the Hindus borrowed their astrology from the Greeks.

the superior planets, on the contrary, the epicycle corresponds in time to a revolution of the sun, and the eccentric deferent answers to the true revolution of the planet in its orbit). *So far the Indian system agrees with the Ptolemaic.* At the first glance it will remind the reader of the hypothesis of an eccentric orbit devised by *Hipparchus :* and of that of an epicycle on a deferent, said to have been invented by Apollonius, but applied by Hipparchus. At the same time the omission of an equant (having double the eccentricity of the deferent) imagined by Ptolemy for the five minor planets, as well as the epicycle with a deferent of the centre of the eccentric, contrived by him to account for the evection of the moon; and the circle of anomaly of eccentricity, adapted to the inequality of Mercury's motions, cannot fail to attract notice. The Hindus give an oval form to the eccentric or equivalent epicycle, as well as to the planet's proper epicycle. *Āryabhata* (the First) and the *Sūrya Siddhānta* make both epicycles of all the planets oval, placing however the short axis of the proper epicycles of Jupiter and Saturn in the line of mean conjunction, termed by Hindu astronomers their 'quick apogee' (Śighrocca). *Brahamagupta* and *Bhāskara*, on the contrary, acknowledge only the epicycles of Mars and Venus to be oval and insist that the rest are circular." (p. 411) "If these circumstances (that is to say, the frequent recurrence of such names as Yavanācārya and *Romaka Siddhānta* in the compilations of Hindu astronomers), joined to a resemblance hardly to be supposed casual, which the Hindu astronomy, with its apparatus of eccentrics, and epicycles, bears in many respects to that of the Greeks, be thought to authorize a belief, that the Hindus received from the Greeks that knowledge which enabled them to correct and improve their own imperfect astronomy, I shall not be inclined to dissent from the opinion." In another article Colebrooke observes (p. 449):— "Taking into consideration the analogy, though not identity, of the Ptolemaic system or rather that of Hipparchus, and the Indian one of eccentric deferents and epicycles, no doubt can be entertained that the Hindus received hints from the astronomical schools of the Greeks."

WHITNEY

Now a *resume** of the views of *Whitney* and *Burgess* will be presented to you. First the result will be reproduced of the comparative view taken by Whitney in the chapter on true places in the English Translation of the *Sūrya-Siddhānta*, in respect of the problem of the true positions and motions of planets dealt with in Greek and Hindu astronomy. Whitney observes : 'It is evident in the first place that in all their grand features the two systems are essentially the same. Both analyze in the same manner with remarkable success the irregularities of the apparent motions of the planets into the two main elements of which they are made up, and both adoptt he same method of representing and calculating those irregularities. Both substitute likewise eccentric circles for the true eliptic orbits of the planets. Both agree in assigning to Mercury and Venus the same mean orbit and motion as to the sun, and in giving them epicycles which in fact correspond to their heliocentric orbits, making the centre of those epicycles, however, not the true, but the mean place of the sun, and also applying to the latter the corrections due to the eccentricity of the orbit. Both transfer the centre of the orbits of the superior planets from the sun to the earth, and then assign to each, as an epicycle, the

* Some of Whitney's arguments have been examined in the proper context. Some of those already examined will be again dealt with further.

earth's orbit ; not, however, in the form of an ellipse, but in that of a true circle ; and here too both make the place of the centre of the epicycle to depend upon the mean instead of the true place of the sun........The differences between the two systems are much less fundamental and important. The moon's evection, the discovery of *Ptolemy*, is equally wanting in the Hindu astronomy. And another innovation introduced into Greek system by Ptolemy is unknown to the Hindus. Ptolemy applies first the whole correction for the eccentricity of the orbit and then corrects the place thus obtained, for the parallax of the earth's position. The Hindus, on the other hand, apply both the corrections twice. The change of dimensions of the epicycles in the odd and even quadrant is also a striking peculiarity of the Hindu system."

In his final verdict Whitney writes : "The application of *bīja* (empirical correction) to the elements of the *Sūrya-Siddhānta* is calculated at least to suggest the suspicion that *Muslim science* may have had something to do with it. That observation and the improvement of their system by deductions from observation were ever matters of such serious earnestness with the Hindus that they should have been led to make such amendments independently, is yet to be proved*.....The Hindu system is not one of nature ; it is a thoroughly artificial structure, full of arbitrary assumptions, of absurdities even which have no foundation in nature, and could be invented by one as well as another. We need only to refer, as instances, to the framework of monstrous chronological periods to the common epoch of the commencement of the Iron Age, with its exact or nearly exact conjunction of all the planets- to the form of statement of the mean motions, yielding recurring conjunctions, at longer or shorter intervals-to the assumption of a starting-point for the planets at or near *Zeta Piscium*-to the revolutions of the apsides and nodes of the planets-to the double system of epicycles-to the determination of planetary orbits etc., etc. These are plain indications that the *Hindu science* emanated from one centre ; that it was the elaboration of a period and of a school, if not of a single master, who had power enough to impose his idiosyncracy upon the science of a whole nation." "The question, then, of the comparative antiquity of single treatises** is lost in the higher interest of the inquiry-when, where and under what influence originated the system which they all agree in representing?......We regard the *Hindu science* as an offshoot from the Greek, planted not far from the commencement of the *Christian era*, and attaining its fully developed form in the course of the fifth and sixth centuries. The grounds of this opinion we will proceed briefly to state. There can be no question that, from what we know in other respects of the character and tendencies of the Hindu mind, we should not at all look to find the Hindus in possession of an astronomical science containing so much of truth. They have been from the beginning distinguished by a remarkable inaptitude and disinclination to observe, to collect facts, to record, to make inductive investigations.... The Hindus have ever been weak in positive science; metaphysics and grammar with, perhaps algebra and arithmetic-being the only branches of knowledge in which they have independently won honourable distinction.... The infrequency of references to the stars in the early Sanskrit literature, the late date of the earliest

* He means to say that the observations of Hindus had not reached that degree of excellence. Though not quite convinced of the truth of this assertion Whitney suggests that the Hindus may have borrowed their *bīja* correction from some Muslim work. This shows the attitude he has taken up.

** This refers to the estimates about the date of the *Sūrya-Siddhānta*.

mention of the planets, prove that there was no special impulse leading the nation to devote itself to the studying the movements of the heavenly bodies. All evidence goes to show that the Hindus, even after they had derived from abroad a systematic division of the ecliptic, limited their attention to the two chief luminaries, the sun and the moon, and contented themselves with establishing a method of maintaining the concordance of the solar year with the order of the lunar months. If, then, at a later period, we find them in possession of a full astronomy of the solar system, our first impulse is to inquire, whence did they obtain it ?" "A closer inspection does not tend to inspire us with confidence in it as of Hindu origin. The whole system may be divided into *two* portions : one containing truth successfully deduced, the other composed of absurd imaginations drawn from Pauraṇic literature. The question presses itself, then, strangely upon us, whether these two portions can possibly have the same origin : whether the scientific habit of mind which could lead to the discovery of the one is compatible with those traits which would permit its admixture with the other. But most especially, could a system founded—as this, if original, must have been-upon protracted observation of the heavenly bodies, so entirely ignore the ground—work upon which it rested, and refuse and deny all possibility of future improvement by like means, as does this Hindu system, in whose text-books appears no record of an observation, and no confessed deduction from observations ; in which the astronomer is remanded to his text-book as the sole and sufficient source of knowledge, nor even taught or counselled to study the heavens except for the purpose of determining his longitude, his latitude and the local time? Surely, we have a right to say that the system, in its form as laid before us, must come from another people or another generation than that which laid its scientific foundation ; that it must be the work of a race which either had never known, or had had time to forget, the observing habits and the inductive methods of those who gave it origin. But the hypothesis that an earlier generation in India itself performed the labours of which the later system-makers reaped the fruit, is well-nigh excluded by the absence, already referred to, of all evidence in the more ancient literature of deep astronomical investigation : the other alternative, of derivation from a foreign source, remains, if not the only possible, at least the only probable one." The absurdities to which Whitney alludes here consist of the Yuga system etc. But in rejecting the Yuga system which had struck a deep root by tradition among our people, one would only incur the stigma of anti-Vedic heresy as is evident from the strictures passed by *Brahmagupta* against *Romaka*. Our astronomers, of course, could not take that risk. Although this may be a serious lapse from the European point of view, it is not so from ours. On the contrary we would rather appreciate the ingenuity that they displayed in reconciling the Yuga system with the hard facts of their science.

Whitney further observes : ' We come, then, next to consider the direct evidences of a Greek origin. The system of epicycles is essentially alike and the same in both systems. Now, notwithstanding the fact that such secondary circles do in fact represent, to a certain degree, true quantities in nature, there is yet too much that is strange and arbitrary in them to leave any probability to the suppositions that the two nations could have devised them independently. But there are sufficient grounds for believing the Greeks to have actually created their own system, bringing it by successive steps of elabroation to the form in which Ptolemy finally presents it. The Greeks tell us what they owed to the Egyptians, what to the Chaldeans : we trace the conceptions which

were the source of their scheme of epicycles, the observations on which it was based, the inductive and deductive methods by which it was worked out and established. In the Hindu astronomy on the other hand, we find neither the conceptions, nor the observations, nor the methods : the whole is gravely put forth as a complete and perfect fabric of divine origin and immemorial antiquity. On the agreement of the two sciences in point of numerical data we will not lay any stress, since it might well enough be supposed that two nations, if once set upon the same track toward the discovery of truth, would arrive independently so near an accordance with nature and with one another."

The scheme of epicycles is not independent in each of the two systems It appears probable that the two systems were inter-related in this respect Whitney, however, does not clearly admit the obvious fact that since the numerical data of the two nations do not agree, it follows that their labours were being carried on independently ; nevertheless, his phrase, "two nations once set upon the same track towards the discovery of truth" amounts to a tacit admission that the researches of the Hindus were independent. Surely no one would say that the researches continued for a day or two and then ended up with the production of some scientific work. The reason why we have no records of ancient observations has already been explained before on page 1.

Whitney then continues : "The division of the circle, into signs, degrees minutes and seconds, is the same in both systems. Now the names of the first sub-divisions, the signs, are the same in Greece and in India. But with the Greeks they belong to certain fixed arcs of the ecliptic, being derived from the constellations occupying those arcs ; with the Hindus they are applied to successive arcs of 30°, counted from any point that may be chosen : this is an unambiguous indication that the latter have borrowed them, and forgotten or neglected their original significance." The author for one, considers it particularly important that we disregarded the original significance of the names Aries, Taurus etc. and applied the names to equal divisions, for these names have got no importance of their own. And even if it be true that they were borrowed from others, they were borrowed before *Hipparchus*, probably from the Chaldeans, as has been shown further on. Whitney then adds : "The Hindu term for 'minute' is no Sanskrit word but taken directly from Greek, being *liptā*. The regents of the days of the week also are not of Hindu origin. On tracing the institution of the week to its very foundation, we find there another Greek word, *horā*. Once more, in the cardinal operation of finding the true place of a planet, we see that one of the most important data, the mean anomaly, is called by another name of Greek origin, namely *Kendra*. These three words, occurring where they do, not upon the outskirts of the Hindu science, but in its very centre and citadel, amount of themselves almost to full proof of its Greek origin ; taken in connection with the other concurrent evidences, they form an argument which can neither be set aside nor refuted. Moreover, the Hindu treatises and commentaries often refer to the *Yavanas*, "Greeks" or "Westerners," and to "*Yavanācāryas*," "the Greek (or Western) teachers" ; and floating traditions* are met with, to the effect that some of the Siddhāntas were revealed to their human promulgators in Romaka-city, that is to say, at Rome. Farther witness to the same truth, deducible

* This refers to p. 37 verse 7.

from other coincidences of the two systems, we pass unnoticed here". The question relating to the days of the week has been considered before (p. 275). The *horās* and the days of the week have nothing to do with the knowledge of the true places and motions of planets, even though they did not originate with us. *Kendra* and *liptā* will be dealt with later. In conclusion Whitney observes : "The question next arises, when and in what manner the knowledge of astronomy was communicated from Greece to India. In reply to this, only probabilities offer themselves, yet in some points the indications are pretty distinct. It is, in our own view, altogether likely that the science came in connection with the lively commerce which, during the first centuries of our era, was carried on by sea between *Alexandria* as the port and mart of Rome, and the western coast of India and that is why *Ujjayin* became the chief site of the Hindu science. Had the Hindus derived their knowledge overland, through the *Syrian*, *Persian* and *Bactrian* kingdoms, the name of Rome would not have stood forth with such prominence and some city other than *Ujjayin* would have been the cradle of the new science. The absence from the Hindu system of any of the improvements introduced by Ptolemy into that of the Greeks and the fact that the numerical elements adopted by the Hindus vary considerably from those of the Syntaxis tend strongly to prove that the transmission of the principal ground work of the Hindu science took place before the time of Ptolemy. Whether the information was transmitted through the medium of Hindus who visited the Mediterranean, or of learned Greeks who made the voyage to India, or by the translation of Greek treatises, or by what other methods, we would not at present even offer a conjecture. Whatever may have been the date of the first communication of that information, there is good reason to suppose that its final reduction to its present form did not take place until some time during the fifth and sixth centuries when the initial point of the fixed sphere coincided with the equinox. It is evident that the elaboration of the system must have been a work of time, probably of many generations. Among the changes of method introduced the most useful and important was the *substitution of sines for chords** ; the general substitution of an arithmetical for a geometrical form also deserves particular notice. That no great amount of geometrical science is implied in any part of the system is very evident ; the equality of the square of the hypotenuse to the sum of the squares of the base and perpendicular—the comparison of similar right-angled triangles—the formation and combination of proportions, the rule of three—are the characteristic features of the early Hindu mathematical knowledge, as displayed in the Sūrya-Siddhānta. Of other treatises which give evidence of knowledge more profound in arithmetic and algebra, we cannot at present speak." It is our good fortune, indeed, that a modicum of praise has fallen to our share from Whitney's pen at last. The writer cannot, however, help adducing here an instance of Whitney's biassed attitude. It consists in this that even though it has become clear at several places, as well as on Whitney's own showing, that the Hindus have borrowed nothing from Ptolemy's works, he characterizes as "not an altogether impossible supposition" the view expressed by *Biot* that the Hindus obtained their sines directly from the chords of Ptolemy or Hipparchus**. Another instance of Whitney's line of reasoning has already been cited while discussing the question of apsides and nodes. (p. 71).

* Though not italicized—by Whitney, these words are printed in bold type in the Marathi original.

** Translation of the *Sūrya Siddhānta*, p. 284.

Burgess

Let us now turn to the verdict of the Rev. E. *Burgess*. Burgess was living in India for a number of years and he had a fair knowledge of our manners and customs ; on the other hand, *Whitney*, living in America, was utterly ignorant in this respect. Evidently Burgess was more competent than Whitney to deliver judgment on this question. Burgess writes :—"I had prepared a somewhat extended and elaborate essay on the history of astronomy among the *Hindus*. But owing to the length of this essay it was not thought advisable to insert it here. However, as my opinions on some points differ from those advanced by Prof. Whitney in his very valuable additions to the notes upon the translation, it seems necessary for me to present at least a brief summary of the results at which I arrived in that essay in reference to the points in question. Prof. Whitney seems to hold the opinion that the *Hindus* derived their astronomy and astrology almost physically from the Greeks—and what they did not borrow from the Greeks, they derived from other people, as the *Arabians*, *Chàldeans* and *Chinese*, I think he does not give the HINDUS the credit due to them and awards to the Greeks more credit than they are justly entitled to. I admit that the Greeks, at a later period, were the more successful cultivators of astronomical science. And yet, I must think the HINDUS original in regard to most of the elementary facts and principles of astronomy and for the most part also in their cultivation of the science and that the Greeks borrowed from them these facts and principles. For the sake of clearness, I should state more specifically a few of the more important facts and principles of this nature. (1) The division of THE ZODIAC into twenty-seven or twenty-eight *asterisms* is common, with slight modifications, to the Hindu, Arabian and Chinese systems. (2) As for the division of the Zodiac into twelve signs, the names of the signs are, in their import, precisely the same in the Hindu and Greek systems. The theory of the division and the names of the parts having proceeded from one original source is unquestionably the correct one. (3) The theory of epicycles adopted for finding the motions and true places of planets is common to the Hindu and Greek astronomies. The coincidenc of the two systems in this respect is such as would preclude the idea of indepenedent origin or invention. (4) Coincidences and even a similarity in some parts between the systems of astrology received among the Hindus, Greeks and Arabians strongly indicate for those systems, in their primitive and essential elements, a common origin. (5) The names of the five planets known to the ancients, and the application of these names to the days of the week.

In regard to these specifications I remark in general :—

"First, in reference to no one of them do the claims of any people to the honour, of having been the original inventors or discoverers appear to be better founded than those of the Hindus."

"Secondly, in reference to most of them, the evidence of originality I regard as clearly in favour of the Hindus ; and in regard to some, and those the more important, this evidence appears to me nearly or quite conclusive."

"A brief remark, for the sake of clearness, seems called for in reference to each of the above five specifications :

(1) As regards the twenty-seven or twenty-eight *asterisms*, the undoubted antiquity of this division, even in its elaborated form, among the HINDUS, in connection with the absence or paucity* of such evidence among any other

* This point did not strike Whitney.

people incline me decidedly to the opinion that the division is of a purely Hindu origin. This is still my opinion, notwithstanding the views advanced by *M. Biot and others* in favour of another origin. (2) As regards the division of the Zodiac into twelve parts and the names of those parts, the use of this division, and the present names of the signs, can be proved to have existed in India at as early a period as in any other country and there is evidence less clear and satisfactory, it is true, yet of such a character as to create a high degree of probability, that this division was known to the Hindus *centuries* before any traces can be found in existence among any other people. As corroborative of this position, I may be allowed to adduce the opinions of *Idcler* and *Lepsius* as quoted by HUMBOLDT* :"Idcler is inclined to believe that the Orientals had names, but not constellations, for the Dodecatomeria and Lepsius regards it as a natural assumption that the Greeks should have added to their own the Chaldean constellations from which the twelve divisions were named." Whether Idcler meant by "Orientals" the Chaldeans, or some other eastern people, the application of the term to the Hindus exactly suits the supposition of the Indian origin of the division in question, since in Indian astronomy the names of the signs are merely names of the twelve parts of the ecliptic, and are never applied to constellations. Humboldt's opinion is, that the twelve divisions of the ecliptic with the names of the signs, came to the Greeks from Chaldea. I think the evidence preponderates in favour of a more eastern, if not a Hindu, origin. (3) The theory of epicycles. The difference in the development of this theory in the Greek and Hindu systems precludes the idea that one of these people derived more than a hint respecting it from the other. But so far as this point alone is concerned, we have as much reason to suppose the Greeks to have been the borrowers as the contrary ; but other considerations seem to favour the supposition that the Hindus were the original inventors of this theory. (4) As regards astrology, there is not much honour, in any estimation, connected with its invention and culture. The coincidences that exist between the Hindu and Greek systems are too remarkable to admit of the supposition of an independent origin for them. But the honour of original invention, such as it is, lies, I think, between the Hindus and the Chaldeans. The evidence of priority of invention and culture seems, on the whole, to be in favour of the former ; the existence of three or four Arabic and Greek terms in the Hindu system being accounted for on the supposition that they were introduced at a comparatively recent period. In reference to the so-called Greek words found in Hindu astronomical treatises, I would remark that we may refer them with propriety to that numerous class of words common to the Greek and Sanskrit languages which either came to both from a common source or passed from the Sanskrit to the Greek at a period of high antiquity ; for no one maintains that the Greek is the parent of the Sanskrit, to the extent indicated by this numerous class of words, and by the similarity of grammatical inflections in the two languages. (5) *Herodotus* says : "The names of the gods came into Greece from Egypt". The names of the planets are names of gods. Herodotus's opinion indicates the belief of the Greeks in reference to the origin of these names. As to the application of the names of the planets to the days of the week, it is impossible to determine definitely where it originated. Respecting this matter, *Prof. H. H. Wilson* observes : "The origin of this arrangement is not very precisely ascertained as it was unknown to the Greeks, and not adopted by the Romans until a

* Burgess has cited the sources from which all these quotations have been taken ; but there is no need to repeat them here.

late period. It is commonly ascribed to the Egyptians and Babylonians, but upon no very sufficient authority, and the Hindus appear to have at least as good a title to the invention as any other people."

"One word on the claims of the Arabians to the honour of original invention in astronomical science. And first, they themselves claim no such honour. That the Arabians were thoroughly imbued with a knowledge of the Hindu astronomy before they became acquainted with that of the Greeks, is evident from their translation of Ptolemy's Syntaxis. It is known that this great work of the Greek astronomer first became known in Europe through the Arabic version. In the Latin translation of this version, the ascending node is called "*nodus capitis*", *i.e.*, "node of the head", and the descending node, *nodus caudee*, "node of the tail"—which are pure Hindu appellations. This tact with other evidence, clearly shows the influence of Hindu astronomy on that of the Arabians. Taking all these facts into account, the supposition that these people were the inventors is altogether untenable."

"As regards the resemblance between the Greek and Hindu methods of calculating the true places of planets, I think that only hints could have passed from one people to the other, and that at an early period ; for on the supposition that the Hindus borrowed from the Greeks at a later period, we find it difficult to see precisely what it was that they borrowed ; since in no case do numerical data and results in the systems of the two peoples exactly correspond, And in regard to the more important of such data and results—as for instance, the amount of the annual precession of the equinoxes, the relative size of the sun and the moon as compared with the earth, the greatest equation of the centre for the sun—the Hindus are more nearly correct than the Greeks, and in regard to the times of the revolutions of the planets they are very nearly as correct. There has evidently been very little astronomical borrowing between the Hindus and the Greeks. And in relation to points that prove a communication from one people to the other, I am inclined to think that the course of derivation was the opposite to that supposed by *Colebrooke*—from east to west rather than from west to east ; and I would express my opinion in relation to astronomy, in the language which this eminent scholar uses in relation to some coincidences in speculative philosophy and religious dogmas, especially the *doctrine of metempsychosis*, found in the Greek and Hindu systems, which indicate a communication from one people to the other : "I should be disposed to conclude that the Indians were, in this instance, teachers rather than learners."

Thibaut

The author now presents the views of *Dr. Thibaut*. In his Introduction to the *Pañcasiddhāntikā* (page 53) he observes :—

"Taken together the five Siddhāntas appear to enable us to form a fairly accurate notion of the transition of old Indian astronomy into its modern scientific form. The *Paitāmaha Siddhnāta*, in the first place, is the representative of the prescientific stage of astronomical knowledge. The *Vaśiṣṭha Siddhānta*, while apparently more advanced than the *Paitāmaha Siddhānta*, yet seems to have been decidedly inferior to the sastric Siddhāntas. We, therefore, shall most probably not be mistaken in assigning it to the period marking the transition from the old purely indegenous systems to those works which were constructed altogether on the basis of Greek Science. The three

remaining Siddhāntas fall under one category, all of them, however much they differ in details, representing the modern phase of Hindu astronomy which is completely under the influence of Greek teaching. The general features of that phase are too well known to require restating in this place. We may, I think, discern certain features in which the Romaka and Pauliśa Siddhāntas agree, while at the same time differing from the *Sūrya Siddhānta*. In the *Sūrya Siddhānta* only modern Hindu astronomy has fully assumed that type which it has since preserved....That the similarities observed between the Greek and Hindu systems are due to a transfer of the elements of the former to India will at present be hardly called into doubt ; and it certainly appears highly probable that the *Pauliśa* and *Romaka Siddhāntas* were the earliest Sanskrit works in which the new knowledge imported from the west was embodied. It certainly is no fortuitous coincidence that one of these two siddhāntas whose names point to the west (the Romaka) used the tropical solar year and calculated its ahargaṇa for the meridian of Yavanapura ; and that the other (the Pauliśa) expressly stated the difference in longitude of Yavanapura and Ujjayinī*. While thus the general question as to the sources of scientific Hindu astronomy admits of one answer only, doubts begin to suggest themselves as soon as we proceed to ask from what particular Greek works the early Siddhānta writers may have borrowed and to what time the first transmittance of astronomical knowledge has to be assigned. Prof. *Whitney* has expressed the opinion that the absence from the Hindu system of any of the improvements introduced into Greek astronomy by Ptolemy seems to favour the conclusion that the original transmission of astronomical knowledge into India took place before Ptolemy, which would account for many differences in detail between the Hindu system and the teaching of the *Syntaxis*. Now with this view we certainly may agree so far as to consider it altogether improbable that the Hindu system should have based directly on Ptolemy's work. Assuming the Hindus to have been acquainted with Ptolemy's work, how shall we explain the numerous discrepancies in essential items of doctrine such as, for instance, the different dimensions assigned to the epicycles of the planets by the Hindus and Ptolemy ? But nevertheless it would be hazardous to conclude therefrom that the beginnings of scientific Hindu astronomy go back to a time earlier than that of *Ptolemy*. The whole question indeed is rendered incapable of decisive treatment by the fact that our knowledge of Greek astronomy anterior to Ptolemy is so very imperfect.

A few points, however, which bear upon it may be briefly referred to. As is well known, the theories of the sun and moon were already settled in all important points by *Hipparchus* and merely borrowed from him by *Ptolemy*. It would therefore, not be impossible that any scientific Hindu work, confining itself to an exposition of the motion of the Sun and Moon and of rules for the approximate calculation of their eclipses, should have originated in the period intervening between Hipparchus and Ptolemy. Hipparchus again had already given determinations of the mean periods of revolution of the five planets

*The *Pañcasiddhāntikā* edited by Thibaut gives the reading *Yavanāntarajā* in place of *yavanāccarajā* occuring in the couplet quoted on page 15 and the context shows it to be correct. In the light of this reading the verse would mean that the Longitudinal distance of Avanti (Ujjayinī) from Yavanapura is ghatis 7-20 and that of Vārāṇasi is 9 ghatis. Yavanapura appears to be Alexandria. According to accurate modern measures, the longitudinal distance of Ujjayini from Alexandria is 7g 38P and that of Vārāṇasi is 8g-51p, which means that the figure given in the *Pañcasiddhāntikā* for Ujjayinī is 2° short and that for Vārānasi is 1° in excess.

which Ptolemy found as means to correct in some very unimportant details only. On the other hand, it had indeed not escaped Hipparchus that the true motions of the planets can be satisfactorily explained, only if we recognise two distinct inequalities ; but he had not undertaken to separate those inequalities in each case and so to establish a workable theory of the planets. The latter achievement Ptolemy distinctly claims for himself, and we therefore must conclude that any Hindu work such as, for instance, the *Sarya Siddhānta* in which the anomaly* of the apsis and the anomaly* of the conjunction are clearly distinguished are later than Ptolemy from whom along, directly or indirectly, they could have derived their theory. The *Pañcasiddhāntikā* says nothing about any planetary rules being given in the *Romaka Siddhānta*, and that treatise in its original form, might, therefore, possibly have been one confining itself to a system of luni-solar astronomy. But none of these considerations compel us to date the *Romaka Siddhūnta* earlier than Ptolemy.

"The *Vāśiṣtha* and *Pauliśa Siddhāntas* treated of the planets also, as we learn from the last chapter of the *Pañcasiddhāntikā*. The earlier set of rules given there apparently distinguishes the two planetary inequalities ; but as we understand the text only very partially, I cannot undertake to discuss the connection of those rules with the Greek science. As far the rules given in the last part of that chapter, they apparently take into account only the anomaly due to the planet's distance from the sun while the anomaly due to the apsis is neglected, and it might perhaps be conjectured that they represent a stage of the theory of planets more primitive than that of Ptolemy. The mean motions attributed to planets in that chapter differ from those determined by *Hipparchus* and *Ptolemy*. But these facts do not, after all, supply valid reason, for supposing any knowledge of astronomical matters to have reached India from Alexandria before the time of Ptolemy. That certain details in the Indian system appear more primitive than Ptolemy's teaching, may simply be due to the fact that the Indian astronomers, with their strictly practical tendency, did not aim at any great accuracy and neglected what in their view would not affect the result of their calculation to an appreciable degree. And there is yet another very important consideration which may account for the divergencies from Ptolemy on the part of Indian works of a date later than his ; and it is, as *Biot* has suggested, that the astronomical knowledge of the Hindus was not derived from any of the great scientific works of *Alexandrian* astronomers, but rather from the manuals used by Greek astrologers (as Biot suggests) and, as we may add, almanac makers. The astronomical views of these men may be presumed to have been rather imperfect and to have diverged in more than one point from the theories of the great scientific astronomers, and it will not be improper to suppose that they might have preserved elements of older, long antiquated doctrines. The *Pauliśa Siddhānta* does not contain theory, but simple practical rules of calculation. If it be supposed that their manuals also contained similar rules, the assumption would, I believe, help to render the whole process of transmission more intelligible. If we suppose that only a very imperfect knowledge of Greek astronomy was transmitted to India, and that Hindu Jyotiṣas endeavoured to erect on that basis a complete system of their own, we can understand how there came into existence works of the types of the *Sūrya Siddhānta* which, although

* Dr. Thibaut seems to have coined these terms for *mandaphala* & *śighraphala* respectively, the more familiar terms being 'equation of centre, and 'annual parallax (R.V.V.).

evincing a fundamental dependence on Greek astronomy, yet show unmistakable traces of originality in numerous details, remaining indeed in by far the greatest number of cases inferior to their original, yet hitting here and there on new devices and methods of undeniable merit and ingenuity.The perfect Hindu system would in that case have to be characterized not either as a mere loan from the Greeks, nor as a mere adoption in the ordinary sense of the word, but rather as a combination and further development. And the merit of originality as far as it goes, would belong to the unknown author of the old *Sūrya Siddhānta.*"

VERDICTS REVIEWED

Let us now proceed to examine these verdicts. Such an examination will enable us to decide the extent to which foreign astronomy exerted its influence over Hindu astronomy. Incidentally, the author will also speak of certain matters which properly belong to the conclusion of this work, such as the various stages in the *growth* of our astronomy and his considered opinions regarding some of the important or controversial questions.

Considering first the mathematical branch, all measures which can be established by means of observations, such as mean motions and positions of planets, and the elements necessary for the calculation of their true motions and positions, *that is* , their equation of centre and annual parallax etc. have originated with our ancient astronomers. If the Greek astronomy influenced our astronomy at all, the influence was confined to the probability that we derived from a foreign source, the principle that a planet's place varies with its *Kendra* (anomaly or commutation), which is its angular distance from its aphelion or apex. This principle became known to us long before Ptolemy's time and thereafter our astronomy developed quite independently. Some other things of minor importance might have been also imported from foreign nations. As regards astrology, it has been definitely concluded that this branch of Joytiṣa is indigenous to our country. Now the grounds for these conclusions will be stated :—

MATHEMATICAL BRANCH

Let us first consider the *gaṇita-skandha.* It will be first proved that the *Siddhāntas* contained in the *Pañcasiddhāntikā* belong to *pre-Ptolemaic period* so that other important questions will be automatically solved. It has been shown before (Page 12) that these five Siddāntas are older than Ptolemy's time. Thibaut, however, holds that they belong to a later period and hence this point shall be considered somewhat in detail here.

Thibaut says that the corrections known as equation of centre and annual parallax which are applicable to the five planets and which are found in the *Vāsiṣtha, Pauliśa* and *Saura Siddhāntas* must have been derived from Ptolemy's works and that, therefore, the Siddhāntas must be more modern than Ptolemy's as if no one else in the world could draw the same conclusions as Ptolemy even if he had the same material accessible to him as Ptolemy. The *Romaka Siddhānta* does not give any calculation of the places of five planets and it resembles the work of Hipparchus. Even then there is no reason, says Thibaut why it should be regarded as more ancient than Ptolemy's time. As a matter of fact there is no evidence for assigning a post-Ptolemaic date to the four Siddhāntas beyond the *ipse dixit* of Thibaut. Let us now consider the other side of the question.

OTHER SIDDHĀNTAS OLDER THAN ROMAKA

It will be first shown that the four Siddhāntas are older than the Romaka. There can be no two opinions as regards *Paitāmaha Siddhānta* being older than the Romaka. As for the remaining three Siddhāntas (Page 12) mention about two grounds has already been made to show that they are older than the Romaka. Moreover the treatment of certain points in the *Vāśiṣṭha Siddhānta*, as given in the *Pañcasiddhāntikā* is* so very primitive as compared with that in the *Romaka Siddhānta* that it can easily be seen that the *Vāsiṣṭha* is older than the Romaka. This will be admitted even by Thibaut, as it appears from his remarks in the forgoing extract. Let us now consider the case of the *Pauliśa* and the Saura. The *Pañcasiddhāntikā* does not mention the year-measure assumed by the Vāsiṣṭha ; if it does, neither Dr. Thibaut nor the author could detect it. Even if it be there, the method given by the Siddhānta for finding the sun's place shows it to be sāyana, being nearly 365^{d}—14^{g}—32^{p}.The methods of the *Vāśiṣṭha Siddhānta* indicate such an infantile state of knowledge that it could not have been regarded as worth copying by the later Siddhāntas. The length of the year mentioned by other Siddhāntas is about $365^{d}\ 14^{g}\ 31^{p}$. The only Siddhāntas other than Romaka, which give the year-measure are the Pauliśa and the Saura. If neither of these had been in existence before Romaka, the Romaka year-length would have been adopted by all the Siddhāntas. The very fact that it has not been adopted shows that at least the Pauliśa and Saura or at least one of them must have been compiled earlier than the *Romaka*. Between the *Pauliśa* and *Saura*, the *Pauliśa* is more primitive than the *Saura*, which means that at least the *Pauliśa* must have been older than the Romaka. In short, the *Paitāmaha*, *Vāśiṣṭha* and *Pauliśa Siddhāntas* are older than the *Romaka*. Thibaut holds that since the *Vāśiṣṭha* and *Pauliśa* Siddhānta mention the two corrections, the equation of centre and the annual parallax, they must have been followers of Ptolemy and, therefore, of a later date. But as a matter of fact the Siddhāntas do not at all give any corrections for the equation of centre and the annual parallax. The last chapter in the *Pañcasiddhāntikā* explains the method of calculating the mean and true places of planets. The author would give here a specimen of the calculation of a planet's place according to it, which will show the truth of his statement. Here is the calculation of the position of Venus**. "Subtract 147 from the ahargaṇa and divide the remainder by 584. The number of rises of Venus is equal to the quotient. The (mean) motion of Venus during this period is equal to 5 degrees of the sign of Scorpio (*i.e.* 7 signs $+5°$) and 20 minutes ; and Venus, after moving through a distance equal to the degrees of *kālāṃśa* (necessary for rise) in 26 days, rises in the west. The 11th part of the number of rises should be added to the ahargaṇa, and the movement of Venus should be calculated on that basis, as follows :—During the three ahargaṇas of 60 days each, it moves through 74, 73, and 72 degrees ; then 77° during the next 85 days and $1\frac{1}{4}$ degree in the next 3 days. Then after becoming retrograde, it moves through only 2° in 15 days. Then it sets in the west after 5 days. After 10 days more it rises in the east. After 20 days more it becomes direct. On each of these three occasions it moves through 4°. Then after moving through 250° in 232 days it sets in the east ; and later on, after moving through 75° in 60 days it again rises in the west." This description contains no reference, explicit or implicit, to the equation of centre and the annual parallax.

* Some of them have been given before (on page 6). For the remaining, Dr. Thibaut's Pañcasiddhāntikā may be consulted.

* See Thibaut's Pañcasiddhāntikā Chapter 18, Verses 1 to 5.

The last chapter of the *Pañcasiddhāntikā* contains an exposition of crude rules of the movements of Venus which were determined after observing them in the sky several times. The Saṃhitā works consider the movements of planets. It is easily seen from this and from works like the *Mahābhārata* that it was the tendency of our people to take first-hand experiences in this direction. Another proof that can be cited in support of this is the fact that the system of beginning the year from the day of Jupiter's heliacal rising was in vogue for several years (page 266). It was based on nakṣatras. Hence, if any mathematical knowledge was borrowed from the Greeks at all, this system must have belonged to an earlier period. The Jovian system was not based on calculation but on observation of the actual position of Jupiter in the sky ; and hence it must have required the experience of observing Jupiter's true positions for centuries. A complete study of the system, therefore, naturally leads one to conclude that rules about the true and mean motions of planets, like those described above might have been formulated from actual experience, or rather necessity might have compelled such formulation. Further it has come to the author's notice that the process of calculation cited above from the last chapter of the *Pañcasiddhāntikā*, does not agree with his actual calculation of ahargaṇa made from the *Sūrya Siddhānta* in that work. Besides, the *Pañcasiddhāntikā* describes the method of finding true positions of planets as given by the *Sūrya Siddhānta*. It, therefore, follows that the calculations described in the last chapter do not belong to the *Sūrya Siddhānta* nor have the processes been determined from the knowledge of the equations of centre and the annual parallax, but simply from the records of observations. In short, the *Paitāmaha*, *Vāśiṣṭha*, and *Pauliśa* at any rate are more ancient than the *Romaka*.

ROMAKA OLDER THAN PTOLEMY

The *Romaka Siddhānta* has been compiled on the basis of the works of Hipparchus. This point has already been discussed. Hipparchus and Ptolemy are very intimately connected. Hence, if Ptolemy's work at all existed when the *Romaka Siddhānta* was transmitted to India, there was nothing to prevent the former from coming here. The very fact, therefore, that it did not come to India proves that the Romaka was older than Ptolemy. It follows then that the *Paitāmaha*, *Vāśiṣṭha*, *Pauliśa* and *Romaka* are older than Ptolemy.

QUINTET OLDER THAN PTOLEMY

There are additional proofs to show that these four and the Saura were all older than Ptolemy. They are :—The length of the year as adopted by Hipparchus and Ptolemy is the same and it has been already shown (pages 13,62) that we have adopted it from neither of them nor from any one else. Similarly none of the following features are common to Ptolemy and our Siddhānta Quintet. Mean motions of planets (Page 66), apsides and nodes (page 69—73) ; *radii vectors* (page 198), inclination of orbits (page 203), precession of the equinox (page 214) ; maximum values of the equation of centre for the luminaries and planets ; the maximum values of the annual parallax of planets (page 242—7) ; obliquity of the ecliptic (page 249) ; parallaxes of the sun and moon (page 329) ; and the *kālāṃśas* of heliacal rise and set (page 331—2). It has been proved in the course of our study of each of these subjects that none of them has been borrowed from Ptolemy. Even though there is no agreement between the two sets of measures, Thibaut maintains that our works,

and especially the equation of centre and annual parallax, are based on Ptolemy's works, and he attributes the variations in figures to the disregard for precision on the part of Hindus. But one who is familiar with our Karaṇa works will never agree to this view. Our works have given 75° or 78° or 80° as the sun's apogee, while Ptolemy has given the value as 65½° which may be the same as the figure given by Hipparchus (see pages 69—72). One may conceivably change the figure 65½° to 65° or 66° ; but how can a difference of 9° or 10° occur at all ? Those who understand mathematical astronomy will have to admit from this that the explanation put forward by Thibaut is not even plausible. It has been shown while discussing the interrelation of different works in the *Adhikāra* on Mean Motions, under the Mathematical Branch, how our people were keen on exactitude when they had to borrow figures from other works. The *Pañcasiaddhāntikā*, Brahmagupta's *Khaṇḍakhādya* and Bhāskara's *Karaṇakutūhala* may be cited as the more conspicuous among the instances in point. Our writers were careful to see that not even an error of a second should creep in. The special types of calculations relating to the sun, moon and the five planets given by Ptolemy are not found in our treatises. Ptolemy's works give Jyās (chords) while ours mention the *Jyārdhas* (half chords). This difference is very important. Even Whitney, a staunch advocate of Greek astronomy, as he is, admits that Ptolemy had nothing to do with the *Sūrya Siddhānta*. In short, all the *Siddhāntas* embodied in the *Pañcasiddhāntikā* are older than Ptolemy. The *Romaka Siddhānta* was imported into India about the beginning of the Christian era some time between 150 B.C. and 150 A.D. The other *Siddhāntas* are even older than that. They must have been compiled at least two or three centuries before Śaka era, and the materials on which they were based must have been in the process of formation several centuries before. It has been pointed out before that the order of these *Siddhāntas* appears to be *Paitāmaha*, *Vāśiṣṭha*, *Pauliśa*, Saura and Romaka (page 25). As the *Vāśiṣṭha Siddhānta* mentions *Meṣa* and other signs, it does not possibly belong to a period earlier than 500 B.S ; it may have been compiled about this date. Even if it be supposed to belong to a much later period, it must have been compiled at least 50 years before Ptolemy, that is to say, earlier than the beginning of Śaka era. Even if it be argued that the *Romaka Siddhānta* was imported into this country shortly before Ptolemy, the *Pauliśa* and *Vāśiṣṭha Siddhāntas* must have already been compiled at least 50 years before the arrival of the Romaka. The *Pauliśa Siddhānta* definitely existed before the Romaka of *Hipparchus* was imported. It may have been compiled some time between 500 B.S. and the beginning of Śaka era.

*Alberuni** states that the *Pauliśa Siddhānta* owes its name to Paulus of Alexandria, and on this basis, some people believe that the Siddhānta was transmitted by the Greeks ; but at the very place where Alberuni makes the statement, he remarks "The *Sūrya-Siddhānta* was compiled by Lāta ; *Vāśiṣṭha Siddhānta* by Viṣṇuchandra, Romaka by Śriṣena and Brahmasiddhānta by Brahmagupta." It is beyond dispute that the Vāśiṣṭha, Romaka and Brāhma, belonging to the *Pañcasiddhāntikā* were not compiled by Viṣṇucandra, Śriśena and Brahmagupta respectively (page 4 and 8). Evidently the three Siddhāntas alluded to by Alberuni, are not the same as those of the *Pañcasiddhāntikā*, and hence the Pauliśa also which is referred to here is not

* *INDIA* Vol. I, p. 153.

the one of the *Pañcasiddhāntikā* group*. Wherever, Alberuni has quoted elements apparently from Pauliśa, they are found to agree with those of the Puliśa cited by Utpala and not with the Puliśa of the *Pañcasiddhāntikā*. Another very important proof has been provided by a sentence of Brahmagupta quoted before (page 7) which indicates that Puliśa and Yavana were quite different persons. It is not that the name Puliśa does not occur anywhere in Sanskrit literature. Obviously, then. Puliśa of the *Pañcasiddhāntikā* has nothing to do with the Greeks. The *Pauliśa Siddhānta* cited by Utpala did not exist in Varāha's time. It must have been compiled by the Yavana referred to by Brahmagupta ; and hence it must have been compiled some time between Śaka 427 and 550.

MEṢA AND OTHER TERMS

Let us now consider for a while the names and divisions known as Meṣa etc. No convincing proofs are available to show that Meṣa and other terms do not belong to us. Greek terms like Kriya, Tāburi, etc. appear in Varāha's *Bṛhajātaka*. But how could priority be definitely assigned as between this set of names and the other set, Meṣa, Vṛṣabha etc. ?
Meṣa and other names might be the translation of *kriya*, *tāburi* etc. or it might be *vice versa*.** The idea of naming clusters of stars from their shapes was familiar to us. The names Mṛgaśirṣa, Hasta, Śravaṇa owe their origin to the imaginary shapes of the clusters concerned. The Nakṣatriya Prajāpati mentioned in Taittirīya Saṃhitā has already been referred to. If it be argued that the regions of Hasta and Śravaṇa are very small areas, the clusters of stars known as Mṛga-nakṣatra, inclusive of the antelope's head and the hunter, and the nakṣatriya Prajāpati are spread over a region comprising more than one *rāśi*. The name Brahmarṣi occurs in the *Mahābhārata* and the *Parāśara Saṃhitā* and it is actually termed *rāśi*. How then could it be said for certain, that our people did not conceive the idea of naming the signs as *Meṣa*, *Vṛśabha* etc. ? Varāha has enumerated the symbols of *rāśis* thus : " Two fishes a small jar, a human couple with a mace and a lute " and so on. Utpala has added parallel quotations in support of these descriptions from *Yavaneśvara* and *Satya* only and not from any *Ṛṣis*. Myths about Meṣa and other signs abound in Western literature but they are not to be found in our own mythology, and the terms have been used in our Literature simply in the sense of the twelfth part of the ecliptic. This leaves room for the suspicion that Meṣa and other names may not be originally ours. But nothing can be positively said on this point. It should, however, be remembered that the system of the days of the week and terms like Meṣa have by themselves, no significance whatsoever. The essence of astronomy lies in the theory and calculation of the true motions and positions of planets. It was by no means an epoch-making change that we substituted the days of the week for the former practice of counting seven days or tithis, as first, second and so on, or adopted terms like Meṣa, Vṛṣabha etc. in place of our original terms " *ṣaḍaśīti* " etc. to denote the twelve divisions of the ecliptic. It has already been shown in the study of *Vedāṅga Jyotiṣa*, *Pāraskara Sūtra* (pt. 1 p. 100) and *Mahābhārata*, that we originally had the twelve parts of the ecliptic. It has also been pointed out in the study of the

* This also confirms the author's former statement (p. 25—26) that the *Sūrya Siddhānta* of the *Pañcasiddhāntikā* group was not compiled by Lāta.

**The connection which the Yavanas have with our system of astrology does not extend as far back as the origin of astrology.

Vedāṅga Jyotiṣa that the system of dividing the circle into 360 degrees and each degree into 60 parts called minutes, must have been originally ours. It seems, however, that the system of indicating planets' places in terms of *rāśis* may have been introduced after the Meṣa and other divisions came into vogue.

Supposing we did borrow from the Greeks the solution of the problems regarding the true places of planets, the absence of the problem in the *Vāśiṣṭha-Siddhānta* shows that the *Siddhānta* belongs to an earlier period ; and since it mentions Meṣa and other divisions, it follows that though Meṣa and other names may have been imported into our astronomy from the Chaldeans or the Egyptians, they were not accompanied by the solution of the problem of true places. It would be shown later on that in all probability we obtained the knowledge of the problem thereafter by our own independent efforts. In view of these facts it cannot be presumed that it reflects any discredit on us, if we derived Meṣa and other names and their corresponding divisions from the Chaldeans or the Egyptians. It has already been explained before (pt. Ip. 139) that the terms were imported about 500 B. C.

What We Borrowed from Greeks.

That the charge, that we have no traditional record of observed results, no aptitude for observation, nor even the habit of observation, is false has been clearly demonstrated at several places before, but especially in the beginning of Part II (Page 1) in our study of the inclination of orbits (p. 203—5) and in the Chapter on "Observations" (p. 221, 234). The oldest extant record of observation is that of an eclipse observed by the Chaldeans in 720 B.C. and that of the Greeks about the winter* solstice observed by Meton in 430 B.C. But we had already been observing the solstices as far back as 1400 B.C. *circa*. The Conclusion of Part I already refers to the question regarding the motions and positions of planets, where it is shown that our people had the tendency towards observing planets. Again, the specimen of the rules regarding planets' true positions as given by Vāśiṣṭha and Pauliśa, cited above (p. 395), would compel one to admit that our people used to observe planets, maintain their record and then deduce rules on that basis. In short, there is no sense in the contention that the Hindus would not be able by themselves to find out facts inferable from observation.

Let us now see if we have derived anything from foreigners with respect to mathematical astronomy. The year measure, mean motions of planets, aphelia and nodes, *radii vectors*, inclination of orbits, precession of the equinox, maximum values of the equation of centre for the sun, moon and the planets, and the annual parallaxes of the five planets, parallax of the sun and the moon, "*kālāṃśas*" for the heliacal rising and setting of planets—none of these was borrowed from *Ptolemy*. *Hipparchus* knew only the method of finding the true places of the sun and moon but not those of the planets. According to Grant** it was not given in any of the Western works compiled before Ptolemy. Whitney and Colebrooke are inclined to the view that the idea of epicycles may have emanated from Hipparchus. The fact that Hipparchus has not compiled any work on the true places of planets this rules out the possibility of assuming that we borrowed the maximum values of the equations

*According to Grant it was the Summer solstice that Meton observed.

**See Grant's History of Physical Astronomy, Ch XVIII and also Thibaut's views on page 392 before.

of centre and annual parallaxes for the five planets from the works of Hipparchus. The measure of the year is the same with Hipparchus and Ptolemy. Even in the opinion of Whitney, Ptolemy adopted the figure for the obliquity of the ecliptic from Hipparchus. It has already been shown that Ptolemy may have adopted from Hipparchus the apogee of the sun and the maximum value of its equation of centre, and neither of these values appears in our works. Similarly, the maximum values of the solar and lunar parallax are not the same with Hipparchus and our works (See page 329). Colebrooke* observes that the Greeks could never secure the accurate measure of the lunar month as was done by the Hindus. It has also been shown in the chapter on observations that we owe nothing to Hipparchus and Ptolemy in respect of instruments of observation. It is therefore beyond dispute that excepting the ideas of epicyclic** system, we have borrowed nothing from whatever is extant as the production of Hipparchus and Ptolemy. Additional important evidences regarding this are as follows :—Both Hipparchus and Ptolemy knew that the ayana point is shifting, and they had determined 36 seconds as its annual motion. But our earlier works do not show any trace of this idea at all. We discovered it later quite independently and fixed the annual motion as about 60 seconds. It matters little what the date of the origin of our astronomy is ; but if the works of Hipparchus and Ptolemy were at all known to us before our science was evolved, how could the precession of the equinox and its motion fail to find a place in our earlier works ? Secondly, Ptolemy*** never knew that the apsides have any motion. Our works, on the other hand, have assumed a motion for them, and that it is so has been proved in the present times. Thirdly, geometry occupied an important place in Greek astronomy but not in ours (See Whitney's remarks). It is evident, therefore, that if we have borrowed anything at all from the works of Hipparchus and Ptolemy, it is nothing more than the notion of epicycles.

If we borrowed anything at all from the Greeks, it must have been done before Ptolemy and Hipparchus. But what was there which the Greeks could claim as their own before the dates of Hipparchus and Ptolemy ? The cardinal function of astronomy is the calculation of the positions of the sun, moon and five planets. All European scholars admit that the Westerners had no knowledge of these subjects before Hipparchus. But the method of finding true places of the sun and moon by the use of the correction for the *equation of centre* is given in the Puliśasiddhānta which was compiled before the Romaka of Hipparchus was imported into this country. This means that the method was already established before the time of Hipparchus. What then did we borrow from the Greeks ?

म्लेच्छा हि यवनास्तेषु सम्यक् शास्त्रमिदं स्थितं ।।

"The Mlecchas are Greeks. This science is very well mastered by them." This verse leads some to believe that we borrowed astronomy from the Yavanas or Greeks ; but it has been shown later on in the study of astrology that this verse chiefly refers to astrology. BRAHMAGUPTA's statement shows that the Greeks had some work on mathematical astronomy, but as already shown before, it was the Puliśa Siddhānta referred to by Utpala and it was compiled after VARĀHA, some time between Śaka 427 and 550. But our astronomy

*Algebra, Intro P. XXII.

**The system of epicycle will be considered later on.

***See footnote on p. 240.

had already been fully developed in the original *Sūrya-Siddhānta* that is, before Varāha's time. The *Pañcasiddhāntikā*, however, mentions at one place, the longitudinal distance of Ujjayinī from Yavanapura. A verse occurs in the *Sūrya-Siddhānta* (Page 37) which purports to say that the Sun-god had assured Maya that he would impart astronomical knowledge to him in the form of a Greek in Romaka City. Similarly Śākalya's *Brahma-Siddhānta* contains this verse :

भूमिकक्षाद्वादशांशे लंकायाः प्राक्च शाल्मले । मयाय प्रथमप्रश्ने सौरवाक्यमिदं भवेत् ।।

शाकल्यब्रह्मसि० अ० १.

" In Śālmala, which is situated 30° to the east of Laṅkā the Sun-god spoke as follows in reply to the first question asked by Maya." This line* occurrs in Śākalya's *Brahma-Siddhānta.* No European is so far known ever to have come across this line. It must, however, be considered when the matter comes up for impartial study. It shows that a dialogue took place between Maya and Sun-god at a place (on the equator) which was situated on the 12th division of the earth's perimeter, that is, 30 degrees to the east of Ujjayinī ; but there is no place (on the equator) 30 degrees east of Ujjayinī, where astronomical knowledge could have been imparted to the Hindus. Hence this statement is not reliable ; still it lends support to the story related in the *Sūrya-Siddhānta.* It makes one believe that the Greeks are in some way related to our astronomy, and the fact that the system of epicycles of both is similar to a considerable degree, further strengthens the inference. It has, however, already been shown before that we have borrowed no numerical data from the Greeks. All things considered, one is inevitably led to infer as the Rev. *E. Burgess* does, that " only hints could have passed from one people to the other and that at an early period (before Hipparchus, in the author's opinion,) for on the supposition that the Hindus borrowed from the Greeks at a later period, we find it difficult to see precisely what it was that they borrowed since in no case do numerical data of the two peoples exactly correspond."

Let us now consider who received such hints and from whom. KENDRA is a very important term. The distance of a planet from the apsis or the apex is its *Kendra* (anomaly or commutation) and it gives rise to corresponding corrections known as equations of *centre* and *annual parallaxes. Kendra* may be a word from Greek or some other language. It does not seem to be Sanskrit. The author is therefore, inclined to believe that the principle of the variation in the mean place of a planet due to its anomaly may have been derived from the Greeks. This principle is, for the first time, noticed in the *Pauliśa Siddhānta* and it has been proved that the siddhānta was compiled before the work of *Hipparchus* arrived in India. Hence, it is evident that the principle was brought to our country before Hipparchus. It is clearly seen from the views expressed by Colebrooke and others that the epicyclic method and the above principle depending on it were never made use of in astronomical calculations by any one before Hipparchus. But Colebrooke says that the epicyclic method was first devised by *Apollonius* before the days of Hipparchus. It was thus introduced into our astronomy through some unknown channel either by Apollo-

*This line was communicated to the author by V. B Ketkar. He came across a break after verse No. 111, in chapter one, in the three different copies of Śākalya's Brahma Siddhānta. (See footnote on page 245), but Ketkar's copy contians verses in continuation of verse 111, and the verse above is one of these additional verses.

nius or someone else who may have been its original inventor. It must, of course, have been imperfect in form and that is the reason why the two methods, Greek and ours, resemble each other and yet also differ to a considerable extent. The *Puliśa Siddhānta* may have had some relation to the Greeks only in respect of the above principle. The *Puliśa* mentions sines, which we have not borrowed from the Greeks; for even Ptolemy's works do not contain them. In short, if we received anything from foreigners, it must have been merely some hints of the epicyclic principle either from the Greeks or perhaps from the Babylonians, and nothing else. We did not receive any detailed information based on observations. We were not as dependent on foreigners as the Europeans think.

Whitney and others have never cared to consider what difficulties stand in the way of an exchange of knowledge in its fullest details between two nations. We have been in contact with the Europeans for about the last 300 years, and during the last 75 years in particular the contact has been so intimate that not even a thousandth part of it could have conceivably been established between any two nations in ancient times. But how much of their astronomy have we imbibed from the Europeans during all these years? Many of us are just aware of the common place fact that *the earth and other planets revolve round the sun.* As for the theory of planetary motions, only the highly educated few may have understood it to a more or less extent; others are perfectly ignorant of it.

The theory of planetary motion propounded in the Greek and Hindu astronomy of the ancient times was doubtless by more difficult to understand than the modern theory. So much about theory taken by itself. Now, how many of those who understand theory really take to actual planetary calculations? It is true that those who understand theory can easily understand the method of making planetary calculations themselves. As it is, however, there can hardly be more than a dozen persons at present in India, who can compute figures from European works. To add to this, there is only a solitary work compiled on the basis of European works, that of Keropant Nana, which is useful for astronomical calculations. When this is the state of things in these days, there was hardly any possibility of anything beyond the exchange of a few simple hints between two nations in ancient times when the chances of astronomers meeting one another were very remote and when there were insuperable difficulties in the way of translation of ideas.

OUR INDEPENDENT EFFORTS

We had begun to the study of mean motions of the Sun and Moon as early as 1400 B.C. (in the Vedāṅga Jyotiṣa period). Kaśyapa and others have referred to the twelve-year Jovian cycle. The cycle was based on nakṣatras and had evidently nothing to do with the Greeks. It shows that the fact that Jupiter's revolution generally takes twelve years, was well known to us in very ancient times and this was true also about other planets. That this knowledge was independently derived is evident from the planetary calculations in the *Vāśiṣtha* and *Pauliśa Siddhāntas* of the *Pañcasiddhāntikā* group. It has been pointed out before, chiefly in the study of the *Vedāṅga Jyotiṣa* and at several other places that the notion of dividing the circle into degrees and minutes may have originally belonged to us. The original *Vāśiṣtha Siddhānta* which has nothing to do with the Greeks mentions these divisions into degrees, minutes

and seconds. Again, it has been demonstrated in the study of the *Mahābhārata* and in the conclusion of Part I that we used to study the positions of planets, their direct and retrograde motions and their conjunctions at a time which leaves no room for suspecting any possibility of connexion between the Greeks and Indians. The *Pañcasiddhāntikā* mentions broad rules stating the number of days which a planet once risen, requires for setting or for becoming retrograde or direct. Even the modern works state such rules, but they are not given any prominance. They appear to occupy an independent place in the *Pañcasiddhāntikā* and *Khaṇḍakhādya* and in this it clearly followed a tradition, because attempts at establishing some such rules might have naturally been made before the correct theory about planetary motion was known ; and that such attempts were made can be seen from the oft-repeated references to them occurring in the *Mahābhārata* and from the rules given in the *Pañcasiddhāntikā*. In short, there is plenty of evidence to show that we had been making independent efforts to create our own resources for formulating the method of calculating the true places of the sun, moon and the planets. Those resources blended with the principle of the equation of centre due to anomaly, stimulated independent thought as in the case of Hipparchus and Ptolemy, till at last their endeavours materialized in the form of the two notable works, the original Puliśa Siddhānta and the original Sūrya-Siddhānta. The divergence which is noticeable at various places as between Greek and Hindu astronomy can be accounted for only if it be assumed that we received nothing from the Greeks other than the mere suggestion regarding the equation of centre varying with anomaly.

Had the word 'Kendra' been one of Sanskrit origin, and had there been no reference to the dialogue between Maya and Sun, and also to the longitudinal distance from Yavanapura, the author would have arrived at the conclusion as the Rev. E. Burgess did, that it was the Greeks who received hints on astronomy from the Hindus. The suggestions which have been received from the Greeks were definitely important and certainly it reflects great credit on the Indian people who independently built up their temple of astronomy on those suggestions with due appreciation and candid recognition of their worth .

James Burgess says that the Hindus received the essence of astronomy from Ptolemy since it is only Ptolemy's works where we find the system of dividing a degree into 60 parts, each of which is further divided into similar parts. But the *Vāśistha Siddhānta* which belongs to a pre-Ptolemaic period mentions such divisions and it is beyond all dispute that the basis of this system, the sexagesimal divisions of the day into ghaṭis and palas, originated with us. As no one among the Greeks except Ptolemy follows the system, it is obvious that it was Ptolemy who borrowed it from Hindus.

Revatī was not originally the first point from which the positions of planets were measured. It was adopted for the purpose about Śaka 444. It has been shown before (pt. 1. P. 139) that the equinox used to occur in Aśvinī about 579 B.C. This implies, therefore, that the initial point or the Aśvinyādi for each of the five siddhāntas of the *Pañcāsiddhāntikā* was not according to Dr. Thibaut's own admission, a fixed point but the position of the equinox, during the period from the date of each siddhānta to Śaka 444. This is perfectly clear so far as the *Vāsistha Siddhānta* is concerned. The *Pañcasiddhāntikā* does not provide any clue to the

epoch adopted by the *Pauliśa Siddhānta* for calculation. Hence, even though its year measure is approximately equal to that of the sidereal year, its initial point must have coincided with the equinox; and since that *Siddhānta* was not in use for many years, its year measure did not affect the results obtainable from it. The original *Sūrya Siddhānta*, however, has adopted the beginning of Kaliyuga as its epoch. With this epoch and the year measure of the *Siddhānta* one finds that its Aries ingress coincided with the equinox about Śaka 451 (Page. 217). But Varāha's remarks clearly indicate that the original Sūrya Siddhānta is not so modern. So the moments of equinoxes computed from the siddhānta would be liable to an error of 1° for every 60 years, to the extent to which its true date may be anterior to the above estimate. This leads one to infer that at the time of the *Sūrya-Siddhānta* one of the two factors—adoption of the Kaliyuga date as the conventional epoch of calculation or the length of the year—must have been different from what it was in the days of Varāha, and what we find recorded by Varāha must have been introduced by someone during a century or two before his time. In any case no numerical data in Ptolemy's works are found in the *Sūrya-Siddhānta*, and independent evidence is available to how that Ptolemy's siddhānta has not reached our country till at least Śaka 500* (see page. 228) ; so, then, whatever be the date of the original *Siddhānta*, the almost finished form in which our astronomy is found was reached without the help of the Greeks. Not a single proof has ever been produced that would compel one to assume that we borrowed from the Greeks some important information other than the principle of the equation of centre depending on anomaly.

FOUNDATION EPOCH OF SIDDHĀNTAS

This principle may have been transmitted to this country before the days of *Hipparchus*, that is, during the 3rd or 2nd century B.C. when the Greek influence had spread far and wide in India. The essentials of planetary calculations were already available, and the *Puliśa Siddhānta* was compiled after the epicyclic principle was introduced here. The Romaka *Siddhānta* was compiled next, and later on, our astronomy very nearly reached the stage of maturity in the original *Sūrya-Siddhānta*. It cannot, however, be said for certain whether it reached that stage a few years before or after the Śaka era.

SAṂHITĀ BRANCH

The origin of the *Saṃhitā* has never been in dispute. The *Saṃhitā* includes several branches of physics ; and it appears that attention may have been naturally drawn first to this branch out of the three ; and it is creditable to us that the branch is our own creation.

JĀTAKA SKANDHA

Let us now consider if we borrowed the astrological branch from the Westerners. Whitney says that *Whish*** and *Weber* have discussed this question in the most satisfactory manner. The author has not seen their writings, he does not know how far the writers are competent to judge this question,

*Even in later years it does not appear to have arrived in our country at any time before Jayasiṃha.

**Whish in the Trans. Lit. Soc. Madras 1827 and Weber in his Indische studien, II, p. 236 etc., (See. Trans. of S.S. p. 174.)

what materials they have drawn upon, and what their arguments are. But he proposes to consider the pros and cons of the question that strike him as worth considering.

*Jacobi** observes that it is in the works of *Firmicus Maternus* (336-354 A.D.) that we find for the first time the system of predicting the future from the horoscope composed of twelve houses. If the system entered India after that date, it must have required at least a century or a half, and it is not at all likely that during the period of 50 to 75 years from that time up to the date of Varāha, as many as six Ācārya (Scholar) authors and five Ṛṣi (sage) authors should have lived and compiled works on astrology. Even this fact alone would suffice to prove beyond all doubt that our astrology is an indigenous growth. The *Titrabiblas*, a work on astrology is said** to be compiled by Ptolemy. The *Almagest*, a work on the effects of planets is also attributed to Ptolemy. But there is no certainty about this. If this be supposed to be true and if it be also assumed that Ptolemy's works were transmitted to India immediately after their compilation, a period of about 350 years appears to have passed between his time (150 A.D.) and that of Varāha. But it has been already shown before (Page 369) that our astrology can be dated back to seven or eight centuries before Varāha. Moreover, the nucleus of the present system of astrology is to be found in the Atharva Jyotiṣa. It mentions only nine 'places' instead of the twelve houses. The first, second and seventh of those nine houses called Janma, Sampat and Naidhana respectively are the same as the 1st, 2nd and 8th in the horoscope of 12 houses. The tenth nakṣatra from the birth-nakṣatra in the Atharva Jyotiṣa is termed *Karmanakṣatra* which under the present day system is the 10th house known as *Karmasthāna* (house of occupation). The remaining places out of nine will be similarly found to correspond to some house or other out of the twelve. The system described in the Atharva Jyotiṣa is said to have been revealed by the sage Bhṛgu. It has been pointed out before (pt. 1., p. 100) that the Atharva Jyotiṣa belongs to a period prior to the introduction of Meṣa and other terms, *that is*, earlier than 500 B.S. It is, therefore, obvious that we had our own independent system of astrology before 500 B.S. It would be easily apparent from this that we imparted to astrology its present form or some form very akin to it, after we had either devised or imported the names of zodiacal signs about 500 B.C. The change thereby effected in the Atharva Jyotiṣa system mainly consisted in the substitution of the ascendant for the moon's place as the first house in the birth chart. An important point in this respect is that the term *Lagna* (ascendant) occurring in the *Vāśiṣtha Siddhānta* bears the same significance as it does in astrology at present. The term could find a place in the *Vāsistha Siddhānta* only because the birth horoscope had come into existence ; otherwise there was no justification for it. It has been proved before that the date of the *Vāśiṣtha Siddhānta* may be as far back as about 500 B.S. or at least 50 years before Ptolemy.

Thus, a very important astrological term like *lagna* was in vogue amongst us, and that the science of natal astrology based on the birth horoscope had originated at a time when astrological works were conspicuous by their absence among the Greeks. The *Bṛhat Saṃhitā* contains a chapter (No. 104) entitled '*Grahacārādhyāya*' which describes the effects of the courses of planets. The

*Weber's History of Indian Literature, page 251.

**See. Trans. of S.S, p. 174. But even Whitney was not sure about this.

first place there in is, of course, assigned to the moon. The chapter refers to Māṇḍavya who was doubtless an author of the Ṛṣi class. This indicates that Māṇḍavya's works laid stress on the lunar horoscope or at least devoted some thought to it. When the twelve *rāśis*—Meṣa, Vṛṣabha etc. came into vogue, the idea of converting the nine-house system of horoscopy into a twelve-house one must have occurred as a natural corollary, and then as a natural course, the system of casting the birth horoscope was first introduced by some sage like *Parāśara* or *Garga*. That system was then communicated to Yavana writers, who compiled works on the subject after 150 A.D. for there is no astrological work of the pre-Ptolemaic period. The Yavanas may have developed it further. The third important point is that Utpala has shown the difference of opinion between Yavaneśvara and Varāha at several places. Varāha himself has cited the views of Satyeśvara at many places, and it is clear from the *Bṛhajjātaka* that they were the only views mainly acceptable to him. Had Yavanas been the pioneers in the field of astrological literature, so much difference of opinion would not have arisen, and Varāha would not have treated Yavana as merely one of a multitude of authors. This shows that the Yavanas were not pioneers in this field.

म्लेच्छा हि यवनास्तेषु सम्यक् शास्त्रमिदं स्थितं ।
ऋषिवत्तेऽपि पूज्यंते किं पुनर्दैवविद्द्विजा: ॥ १५ ॥

बृहत्सं. अ. २.

"The Mlecchas are Greeks. This science (of astrology) is well established among them and hence they are to be respected like sages. It goes without saying, then, that the Brahmin who knows fate (astrology) also ought to be respected all the more."

Varāha has quoted this verse from *Garga*. Garga simply says here that the science is well established among the Yavanas. Some people are inclined to infer from this quotation that we entirely borrowed Jyotiṣa (astrology as well as astronomy) from the Yavanas, and that is a mistake. The context of the verse shows that it has nothing to do with the science of astronomy ; and our people never regard Jyotiṣa as a science confined to mathematical astronomy only or as representing the main branch of astronomy. They regard Jātaka and Saṃhitā as the main branches. Of these two, the Saṃhitā branch has no connexion with the Yavanas. The above verse, therefore, refers only to the science of astrology. This is also evident from the word daivavit (one who knows fate) used in it ; and the purport of the verse is : "This science is well developed among the Yavanas, and they are worthy of respect even though they are Mlecchas. Need it be said, then, that the Brāhmana who also understands astrology, ought to be respected ?" This does not mean that we borrowed the whole of the science of astrology from the Yavanas.

Some are inclined to believe that since our works on astrology contain some 'Yavana' terms, astrology originally belonged to the Yavanas. But it is a wrong notion. Let us consider the point. Weber and Kern say that the *Bṛhajjātaka* contains 36 Greek words. It may now be mentioned where these words occur and their meanings. The following names of the twelve *rāśis* from Meṣa onwards are given from *Chapter I*, verse 8 :—*Kriya, Taburi, Jituma, Kulīr, Leya, Pāthena* (*Pāthona*), *Jūka, Kaurpya, Taukṣika, Ākokera*,

Hridroga, *Ittham*; verse 9 contains the words *horā* (half of a sign) and *dreṣkāṇa* (decanate or third part of a sign) ; verse 15 :—Ripfa (the 12th house in the horoscope) ; Verse 16—*Dyūna* (The 7th house); verse 17 :—*Kendra* (angular houses *i.e.* the 1st, 4th 7th, and 10th) ; verse 18 :—*Paṇaphara* (succeeding houses i.e. the 2nd, 5th, 8th and 11th), *āpoklima* (cadent houses or the 3rd, 6th, 9th and 12th) ; *hibuk* (the 4th house) *yāmitra* (the 7th house), *Trikoṇa* (the 5th house), *meṣūraṇa* (the 10th house) ; verse 20 :—'*Veśi*' (the house next to the one occupied by the Sun). Chapter II, Verse 2 contains :—*Heli* (Sun), *Himna* or *Hemna* (Moon), Āra (Mars), *Koṇa* (Saturn) ; Verse 3 :—*Āsphujit* (Venus). Chapter XIII, verse 3 contains the following aspects :—*sunaphā*, anaphā, durudhara, kemadruma. (The *sunaphā* aspect occurs if any planet, other than the sun occupies the 2nd house from that of the Moon ; the aspect is '*anaphā*', if it be in the fifth house ; it is *durudhara*, if both the houses are occupied by some planet ; and in the absence of any of these three, the aspect is *kemadruma*). Chapter VII, verse 10 contains the term *Liptā* (*kalā*). This is a term from astronomy. There are thus 34 words *in all. Other additional words are said to be *jyau* and *dyuta*. But the author did not come across the word *dyuta* or *dyūta* anywhere ; if there be such a word at all, it may be indicative of some house. Weber appears to suggest that the word *jyau* is to be found in Chapter II, verse 3. But the word is definitely not to be found there. The word *ījya* is found instead ; and this Sanskrit word as is well known, stands for Jupiter. Utpala too has taken it as *ījya*. The word *ittham* has also been taken by Utpala as the Sanskrit word, meaning *thus*. *Kulīr* is a well-known Sanskrit word. Again the words *Hridroga*, *trikoṇa*, *Hemna*, *Koṇa* cannot be said to be Greek only and not Sanskrit also. Even if it be presumed that all the foregoing words are Greek, the author wonders why one should make a great fuss about them. It does not necessarily follow from the adoption of these words that the horoscope of twelve houses was utterly unknown to us and that we borrowed it from the Greeks.

It has been shown before that the very idea of the horoscope first originated in our country ; and if that is true it is immaterial that so many Yavana words have crept into our treatises. It will only prove that a number of works of Yavana writers were in wide circulation in our country, and that these words were admitted into our literature because the works were in circulation. The word *book*, for instance, has come into our general use these days, but the thing denoted by it already existed here as is indicated by the corresponding word *pustak* etc. Now supposing the *book* which is now so very familiar to us becomes extremely dominant in future, *pustak* may come to be ousted from everyday language and relegated to literary work. Even then it would not mean that the idea of the thing denoted by *book* was originally not our own. This holds good also in regard to the above list of 36 words and the objects represented by them. Another point for consideration is that when a word has several synonyms, that one is apt to be selected which is found to be metrically most suitable. In the same way, many of these 36 words have been used in verses for the sake of metrical convenience. At several places, their Sanskrit synonyms also have been used. Out of these 36 words, there are 12 which stand for the names of the 12 signs, *Meṣa* etc ; even then ther do exist Sanskrit synonyms for them. *Heli* and other words represent th

*These words appear in the Bṛhajjātaka at some other places also. But only the more important places have been mentioned above, along with their more important meanings. The Bṛhajjātaka along with Commentary may be seen for detailed information for their different senses and for *Sunaphā* and other aspects.

six planets, which also have Sanskrit words ; and there can be no doubt about the fact that we obtained knowledge about them quite independently. Eleven words including *ripfa*, *āyūna*, etc. indicate the different houses of the horoscope. But these too have Sanskrit synonyms for them; *liptā* is a mathematical term and *kalā* is a Sanskrit synonym for it. Now, only six words remain: *horā*, *dreṣkāṇ*, *sunaphā*, *anaphā*, *durudhara*, and *kemadruma*. These, however, have no Sanskrit equivalents. Sunaphā etc. are names of Greek aspects, and we may have borrowed them from Greek works. But that is immaterial. Our works abound in hundreds of other aspects, and we have borrowed from Yavana works only four more, like *sunaphā* etc. which appeared worth adopting.

Horā and *dreṣkāṇa* are, however, words of greater importance. But it is not that the cream of the horoscope lies just in these two words. Colebrooke remarks that our *dreṣkāṇa* system is somewhat different from that of the Chaldeans and Egyptians. But as the three have also certain points of resemblance and as the word *dreṣkāṇa* is not one of Sanskrit origin, he appears to have been led to attach importance to the word and to conclude that Hindu astrology is not an indigenous growth. But if his view rests only on such flimsy evidence it is indeed an erroneous view.

He who fully understands astrology will easily see that it is not that *horā* and *dreṣkāṇa* are very important and indispensable features of astrology. Their combined importance may be even less than five per cent. Hence, all things considered, the presence of 36 Yāvanī (Greek) words in our treatises does not conclusively prove that our science of astrology is not our own production. In short, the *Jātaka* branch is our own from its very inception. The only connexion it has with the Yavanas consists in the fact that our astrology assimilated part of Yavana system at a later stage.

RETROSPECT AND PROSPECT

We have already seen the various phases through which our growing science of astronomy has passed. If works compiled before Varāha mihira and those in the intervening period between Brahmagupta and *Rājamṛgāṅka* would become accessible, we would know more of the history of the science. Research work in the Saṃhitā Branch came to a standstill very soon after Varāha. The mathematical branch was in a flourishing condition till about Śaka 1000. Bhāskarācārya's treatises threw into the shade most of the previous works and from that time onwards the theory propounded in Bhāskara's works came to be regarded as the alpha and omega of the knowledge of astronomy. As the divorçe between planetary calculations and the realities of the heavens became more palpable in course of time, there appeared on the scene some annonymous *bīja**-*finder* of the *Sūrya Siddhānta*, as also Keśava Daivajña and Ganeśa Daivajña, and they rectified the elements of the planets. They could not, however, revitalize the science and ensure its future growth. The corrections (*bīja-saṃskāras*) proved to be mere makeshifts of the moment in the absence of the tradition of recording observations, and these corrections were in certain respects not quite accurate. Another great drawback of such corrections was that they led to the general belief that the difference between the results of calculation and those of observation was due to a cumulative error traceable

*It is not known who devised the *bīja* (correction) for the *S. S.*

right back to the beginning of the Kaliyuga, and hence the corrections were so devised that the error which had really accumulated in a few years was spread over a very long period. Consequently the corrections could not remain valid for a long time, and in certain cases they proved useless from the very beginning. A glaring instance of this is that the year-length once handed down in the remote past was never corrected later, with the result that at present the correction of the year-length has become the toughest problem affecting the question of calendar reform. Even though Brahmagupta noticed that the equinox receded a day, he distributed the difference over a period of 3700 years according to the traditional belief, that all variations originated at the beginning of Kaliyuga, though in reality the difference was the result of the error accumulating since Āryabhaṭa's time, that is, a period of about 150 years. Otherwise, Brahmagupta himself could have introduced the measure of the tropical year ; and once he had introduced it, calendar reform would not have been an uphill task as at present. Even the observations of Keśava and Gaṇeśa proved to be of little use. Had there been a record of past observations, it would have been of much use to them for comparing results. In short, although corrections were applied from time to time, they could rectify the planetary elements only for the time being.

The superstitions that our ancient works are *apauruṣa* (divine) and perfect in every way, and the consequent feeling of reverence which even the *pauruṣa* (man-made) works of Āryabhaṭa and Brahmagupta inspired as if they were also of divine origin proved very detrimental to the growth of astronomical science. It engendered the belief that our duty was strictly confined to the occasional correction of elements whenever planetary calculations failed to accord with observation and that this too was not to be done independently but under the name of *bīja* applicable to the original work. It was due to this, coupled with the fact that protracted observations ceased for want of royal patronage, that no new discoveries were made in India as they were made in Europe. The cessation of royal patronage must have been also due in a large measure to the self-complacence of the astronomers who believed that, thanks to the older treatises, they were not duty bound to do anything more. Had the astronomers been alive to their duty, they could have secured royal support. Again, owing to Muslim domination most of the eminent princes of Southern India had vanished after Śaka 1300 and the same fate had befallen those of the North even earlier. The peace of the country was disturbed, and this also proved to be a great obstacle to the growth of the science. In spite of this, it is a matter for pride that in many a village like *Nāndgaon* in the Konkan, *Pārthapura* on the bank of the Godāvari and *Golagrāma*, and at the academy of Vārānasi, there arose among our people observers like *Keśava* and *Gaṇeśa*, theorists like *Kamalākara*, and designers of instruments like Padmanābha, each one ploughing a lonely furrow. When peace had hardly been restored under the rule of the Marathas and Peshwas, when the tradition of taking observations was just being revived by designers like Cintāmaṇi Diksit (P. 174) and when the knowledge of theory, almost lost, thanks partly to works like the *Grahalāghava* and partly to other reasons, was just being recovered by scholars like Yajñesvar, the commentator of the *Laghu Cintāmaṇi*, the rule of the Peshwas ended. The efforts made by such men as Jayasiṃha on a grand scale at Delhi, Ujjain and Jaipur apparently came to an abrupt end, because of political unrest. Since the advent of British rule, peace reigns supreme and learning is being fostered. But practically no facilities have been provided for the critical study of mathematical astronomy and other

profound and interesting aspects of that science. On the contrary the printing press has proved to be a new menace to the growth of astronomy, for, the almanac-makers who were once to be found practically in every town are fast vanishing, being no longer in demand. In these circumstances who would care to study theory works like those of Bhāskarācārya ? However, the mathematical branch has somehow managed to remain alive because the necessity of muhūrtas, and the ardent desire of the people to know the future in the light of astrological works persist even to-day and are bound to persist in future to the same degree as before, and the Joshis are compelled to do at least some planetary calculations. Natal astrology is in a fairly good condition, if not flourishing as vigorously as before, but that can hardly add to our credit.

Copernicus compiled his work in Śaka 1465. Prior to this date European astronomy was practically in the same condition as astronomy in India. The great difference between the two, however, was that the European science was progressive while ours was stagnant. It was not very long before Copernicus, that Gaṇeśa Daivajña and his father Keśava Daivajña, both of them research-loving scholars, were flourishing in our country. But with the advent of Copernicus, European astronomy passed through such a tremendous change that while the science of the by-gone days was comparable to the newly grown sapling of the Banyan tree, the latter-day-science was the Banyan tree itself, towering in the full-grown majesty of centuries, yielding shade and shelter to thousands. Ours has merely clung to the *status quo ante* .*

One of the important reasons why the science of astronomy has attained the highest degree of excellence in Europe to-day is navigation. This does not hold good in our country, still there are other reasons that necessitate the study of astronomy. The first of these is the need of compiling the almanac, which includes the needs of both Dharma śāstra and Muhūrta. Astrology is the second reason and curiosity the third. Some are of opinion that our old astronomy has become utterly worthless, that nothing would be amiss if the almanac is lost. But even a little enquiry will show them that none of the ancient nations put in as much effort as our ancient ancestors did in the sphere of astronomy, and that they could achieve much greater success in it than in any other empirical science like medicine. Again, if they give some thought to the state of things in the villages, they will come to know that 90 or even 95 per cent of the population do require the almanac. The educated modernist may choose to ignore the almanac, but that does not mean that the common man would follow suit. In fact our astronomy owes its origin to the necessity of the almanac which serves as the mirror of the heavens. The educated people, however, would be justified in demanding that the almanacs should be reformed and in wishing that our feeling of veneration towards astronomy should be directed to some more desirable channel. But they are not justified in repudiating the almanac itself or the sense of veneration which it inspires.

DUTIES AHEAD

We have already studied the question of calendar reform in elaborate detail and three possible modes of reform have been suggested (P .323). It is highly desirable that all people should carefully consider and decide by the

*See *Jyotirvilāsa*, (2nd edition) pp. 51 and 52.

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vation and to give them information about the history of our ancient works, in order to induce them to study the astronomical theory by the old or new methods ! Efforts made in the way to awaken the nation as a whole are bound to have a more lasting, even if slow, effect as compared with the isolated action taken in this respect. If our ancient instruments and ancient works are collected together and preserved in some principal cities in our country and if observatories are built for taking observations both by the ancient and modern methods, and institutes for study are established, the science of astronomy once brought to a splendid condition by our ancestors will not only recover its former splendour but even grow more brilliant. The threefold duty suggested above for *Śaṅkarācārya* and others in respect of the question of calendar reform is only the first step towards curing the malady. But we ought to aim at some achievement of lasting value rather than ephemeral results. This tree of astronomy was planted in excellent soil in our country and was growing very vigorously in ancient times. It was being watered from time to time. People used to feel gratified on tasting its fruit. The fragrance of its flowers had not only spread far and wide not only in this country but had also reached even the remote lands of the earth. And although in very ancient times some wind-borne clouds of distant skies—the foreign astronomers—may perchance have let a few drops of water fall into its basin, history shows beyond doubt that the seed thus begotten was wafted back to those foreign lands and a new tree of astronomy began to grow there, or the old one was revived. Glorious and flourishing as our tree was, its growth was arrested in course of time. It ceased to receive water ; and naturally its tender foliage has withered. The tree is now feebly clinging to life somehow, thanks to the water received in ancient times and the few drops that trickled down later on rare occasions, and it is still yielding fruit of a sort, sour and bitter. As we look abroad, however, we find that the sapling which owes its origin or revival to this very tree on the Indian soil has grown and is still growing so vigorously that thousands of people are getting shelter in its shade. The astounding expansion of the offspring would hardly lead one to suspect that it had ever any kinship with the parent tree in India.

The reason why such a glaring contrast has arisen is mainly that the science abroad has been nurtured on the labours of the observatories. May Savitā the Almighty inspire all of us to endeavour in order that observatories may be established in India, and that our science, revitalized and set on the path of progress, attain the acme of perfection. And now that the time is ripe for planting the seeds of knowledge, as already remarked, may we have facilities for renovating the science as was sought to be done from time to time in the past, in the guise of empirical corrections (*bījasaṃskāra*) and is still being done to some extent. And may there arise, men inspired by the self-evolved Savitā, who would bring about such consummation through original works on the science.

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